



Technical Report CHL-97-16
August 1997

Navigation Conditions at LaGrange Lock and Dam, Illinois Waterway

Hydraulic Model Investigation

by Ronald T. Wooley

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by Ronald T. Wooley

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

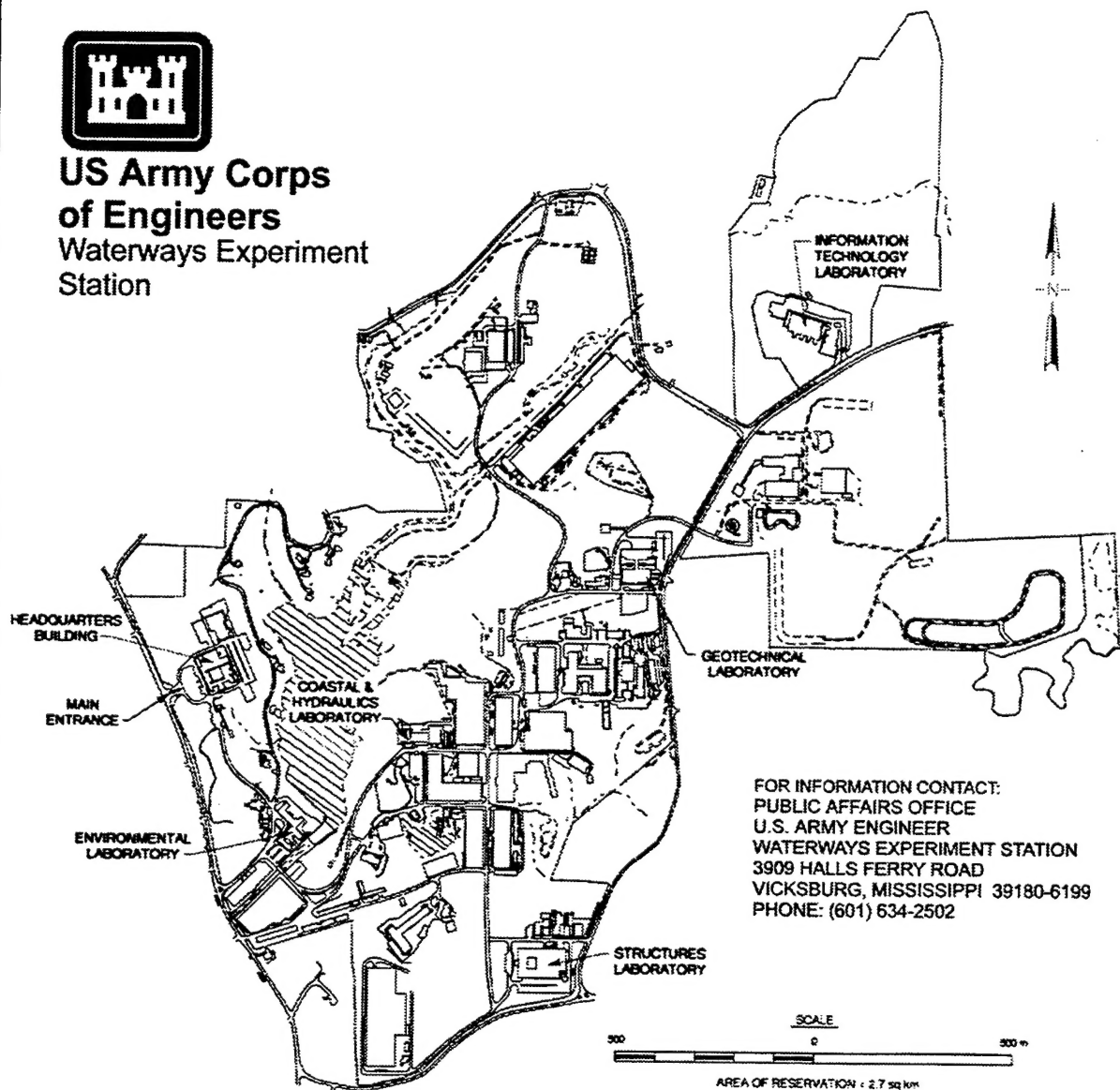
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Preface

This model investigation was conducted for the U.S. Army Engineer District, Rock Island. Personnel of the Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES), conducted the study from September 1985 to March 1987.

During the course of the model study, representatives of Rock Island District and other navigation interests visited WES at different times to observe special model tests and to discuss test results. The Rock Island District was informed of the study's progress by monthly progress reports and special reports at the end of each test.

The model study was conducted under the general supervision of Messrs. F. A. Herrmann, Jr., Director of the Hydraulics Laboratory (retired), and R. A. Sager, Assistant Director of the Hydraulics Laboratory; and under the direct supervision of Messr. J. E. Glover, former Chief of the Waterways Division, Hydraulics Division; M. B. Boyd, Chief of the Waterways Division (retired); L. J. Shows, former Chief of the Navigation Branch, Waterways Division; and Ms. C. M. Holmes, Chief of the Navigation Branch. The principal investigator in immediate charge of the model study was Mr. R. T. Wooley, assisted by Messrs. E. Johnson, E. A. Frost, J. W. Sullivan, and Ms. D. P. George, all of the Navigation Branch. This report was prepared by Mr. Wooley.

This report is being published by the WES Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and Hydraulics Laboratory. Dr. James R. Houston is the Director of the CHL and Messrs. Richard A. Sager and Charles C. Calhoun, Jr., are Assistant Directors.

Director of WES during preparation and publication of this report was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurements

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
inches	25.4	millimeters
miles (U.S. statute)	1.609347	kilometers
square miles	2.58	square kilometers

1 Introduction

Location and Description of Prototype

LaGrange Lock and Dam are located on the Illinois River at river mile 80.2, 8 miles¹ downstream from the city of Beardstown, IL (Figure 1). The structures include a 110-ft-wide by 600-ft-long navigation lock with a nominal lift (maximum) of 10 ft; a 540-ft-wide navigable pass with 135 wickets at 4.0 ft center to center; a 136-ft-wide regulating weir; and a 390-ft-long earth dam with top elevation² of 430.0. LaGrange Lock and Dam maintains a 78-mile-long navigation pool at el 429.0 that extends upstream to the Peoria Lock and Dam near Peoria, IL. The tailwater at LaGrange Lock and Dam is controlled by Lock and Dam 26, 95 miles downstream from LaGrange, on the Mississippi River near Alton, IL. At higher riverflows, when the tailwater exceeds approximately el 437.0, the dam is taken out of operation and the upper pool and the tailwater gauge level are virtually the same, allowing navigation over the wicket dam.

The average annual precipitation at Rushville, IL (13 miles west of LaGrange), is 36.8 in., which occurs mostly April through September. However, heavy precipitation and flooding can occur during any month of the year. The Illinois Waterway at LaGrange has a drainage area of about 26,000 square miles. An estimate of the flow at the LaGrange Lock and Dam was based upon the nearest Illinois Waterway measured river gauge, which is at Meredosia, about 8.9 miles below the dam. Stage height was based on the pool gauges at the dam. About 40 years of records were available to develop a rating curve at the dam.

Conditions of Preproject Structures

The normal pool at LaGrange Lock and Dam is controlled by 135 wicket gates and a regulating structure. Each wicket has two stationary positions, a raised position and a lowered position. During low riverflows, all wickets are raised and the upper pool is controlled by a regulating structure adjacent to the left bank. Although the dam has eight flip-top or hinged wickets to pass ice and

¹ A table of factors for converting non-SI units of measure to SI units is found on page vi.

² All elevations (el) are in feet referred to the National Geodetic Vertical Datum (NGVD).

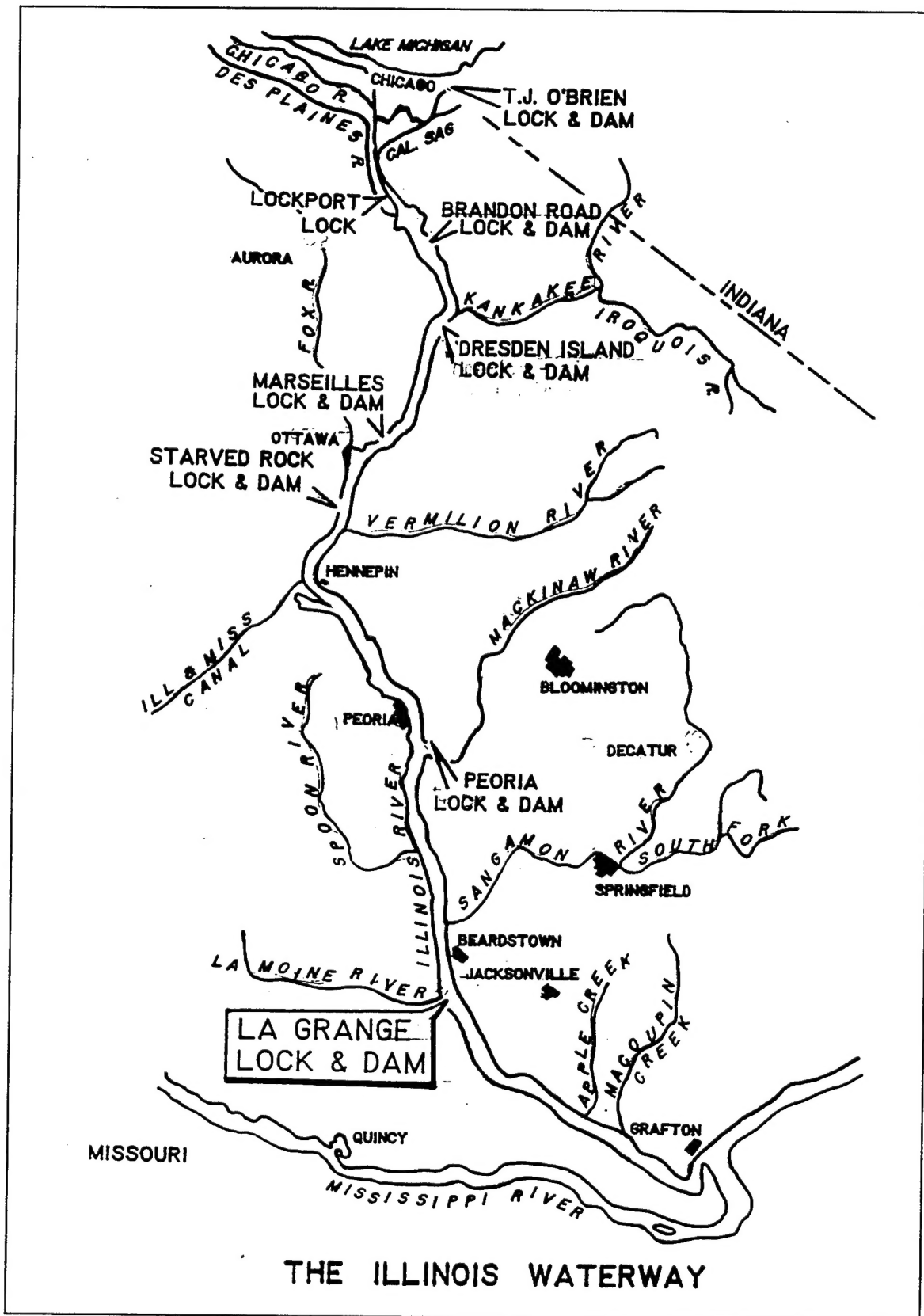


Figure 1. Location and vicinity map

debris (adjacent to the lock), they cannot sufficiently pass heavy ice flows. Frequently, during winter, ice lockage is required to move large quantities of ice past the dam while tows wait for a clear lock. Flow regulation with the wickets is undesirable but necessary at the time of this study since the regulating structure provides only minimal regulatory capacity. The wickets must be lowered and raised manually; therefore, it is a time-consuming and, in some cases, a potentially hazardous operation.

Present Development Plan

The present plan alleviates some problems of the wicket dam by replacing some of the wickets adjacent to the lock with a submersible tainter gate. The tainter gate would regulate the navigation pool under normal conditions and could be submerged to pass heavy ice flows. The tainter gate eliminates the need for using the wickets for pool regulation, therefore greatly reducing the raising and lowering of the wickets.

Need for and Purpose of Model Study

Although the proposed design and placement of the tainter gate were based on sound theoretical design practice and experience, conditions through the reach could be expected to be extremely complex. This could be attributed to the currents in the vicinity of the lock, irregular channel alignments and configurations, limited channel width, crosscurrents, and high velocities. Navigation conditions vary with location and flow conditions upstream and downstream of a structure, so an analytical study to determine the hydraulic effects from a particular design is difficult and inconclusive. Therefore, a comprehensive model study was considered necessary to

- a. Determine the effects of the proposed tainter gate on navigation conditions.
- b. Develop modifications to improve navigation conditions.
- c. Evaluate navigation conditions for tows entering and leaving the lock and moving through the navigation pass with a range of riverflows.
- d. Investigate the effects of the completed project and the cofferdam on water-surface slopes through the reach.
- e. Investigate the effects on navigation during the construction stage of the project and develop modifications necessary to maintain safe navigation through the reach.
- f. Determine the potential for scouring of the channel downstream of the proposed tainter gate.

The model also demonstrated the conditions resulting from the proposed design and satisfied the design engineers and navigation interests about the design's acceptability.

2 The Model

Description

The model is a scale reproduction of approximately 2.1 miles of the Illinois Waterway and adjacent overbank, from mile 79.3 to mile 81.4, with lock and dam structures, regulating structure, and levees that affect flow or navigation within the reach. The model is a fixed-bed type with the channel and overbank areas molded in sand-cement mortar to sheet metal templates; the lock, dam, and regulating structures are constructed of sheet metal and Plexiglas. Provisions were made in the model to remold the area immediately downstream of the dam to reasonably represent projected scour patterns for the revised structure.

The model channel reproduces a hydrographic survey dated June 1985 except for an area 1,000 ft upstream and downstream of the wicket dam that was constructed to a hydrographic survey dated November 1984. The overbank area reproduces Illinois Waterway maps 80A and 81A, which were compiled in 1981 from 1978 and 1979 aerial photography. The reproduced overbank areas extended to the existing levees except along the right bank from approximately 1,900 ft upstream of the dam axis to the lower end of the model, which was reproduced to approximately el 434.0. Levees and model limits were constructed to a grade sufficient to confine the 102,000-cfs riverflow (maximum navigation riverflow of interest to the U.S. Army Engineer District, Rock Island).

Scale Relations

The model was built to an undistorted scale of 1:100, model to prototype, to effect accurate reproduction of velocities, crosscurrents, and eddies affecting navigation. Other scale ratios resulting from the linear scale ratio are as follows:

Characteristic	Dimension ¹	Scale Relation
Area	$A = L^2$	1:10,000
Velocity	$V = L^{1/2}$	1:10
Time	$T = L^{1/2}$	1:10
Discharge	$D = L^{5/2}$	1:100,000
Roughness (Manning's n)	$n = L^{1/6}$	1:2.15
¹ Dimensions are in terms of length L		

Measurements of discharges, water-surface elevations, and current velocities can be transferred quantitatively from model to prototype equivalents using these relations.

Appurtenances

Water was supplied to the model by a 5-cfs centrifugal pump in a circulating water-supply system. The discharge was controlled by valves and measured at the upper end of the model with a venturi meter or a Van Leer Weir to cover the wide range of riverflows. The water was introduced through a 12-in. baffle pipe into a 3-ft-deep headbay with two baffle walls in an effort to distribute the flow evenly across the channel. Water-surface elevations were measured by 10 piezometer gauges located in the model channel and connected to a centrally located gauge pit. Water-surface elevations in the model were controlled by a motorized slide type tailgate centered in the channel at the lower end of the model.

Velocities and current directions were measured in the model by cylindrical wooden floats submerged to the depth of a loaded barge (9-ft prototype). Confetti and dye were also used to determine current patterns in eddies. A miniature current meter measured spot velocities. A radio-controlled model tow and towboat, equipped with twin screws, Kort nozzles, and forward and reverse rudders, and powered by a small electric motor operating from batteries in the tow, were used to study and demonstrate the effects of currents on navigation. The tow in the study represented fifteen 195-ft-long by 35-ft-wide standard barges with a 150-ft-long pusher. This provided an overall size tow of 1,125 ft long by 105 ft wide loaded to a draft of 9 ft (Figure 2). The towboat operated in forward or reverse, at various speeds, and with variable rudder settings. It was calibrated to the speed of a comparable size prototype towboat moving in slack water and operated at 1 to 2 miles per hour above the speed of the currents to maintain rudder control but not overpower the currents. Multiple-exposure photographs recorded the path of the tow with the various conditions.

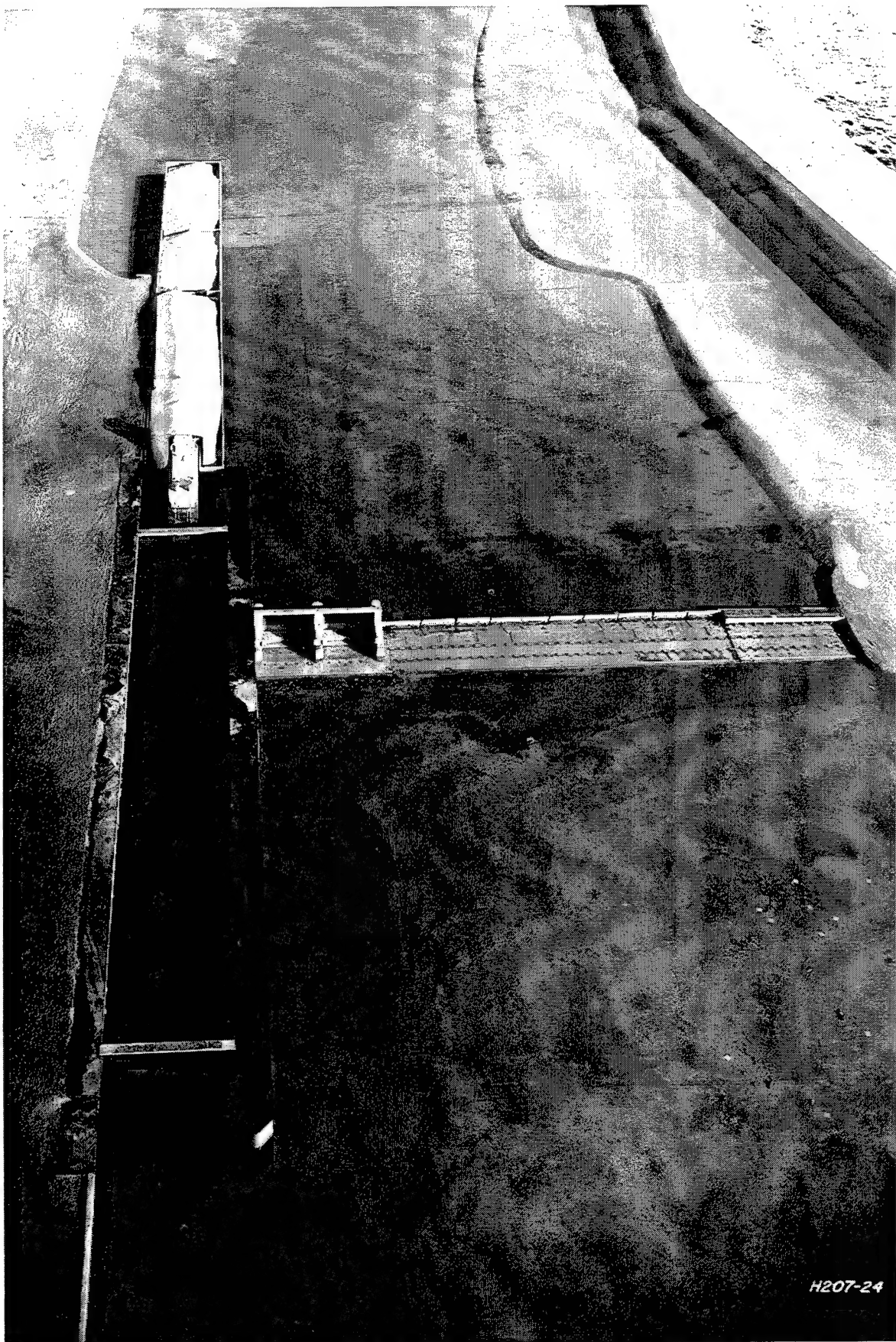


Figure 2. Radio-controlled towboat and tow in upper approach of lock

Model Adjustment

Prototype current directions and velocities were not available for model adjustment; therefore, current patterns at the entrance to the model were adjusted to reflect normal patterns that occur with the channel configuration reproduced. Water-surface elevations with the various riverflows were compared to prototype slopes and were within acceptable limits and adequate for the model study. The regulating weir discharge and the leakage between wickets were adjusted to discharge ratings provided by the Rock Island District.

3 Tests and Results

Experiments were concerned primarily with the study of flow patterns, measurements of velocities and water-surface elevations, and the effects of currents on the movement of the model tow into the lock approaches during low riverflows and through the navigation pass during higher riverflows.

Experiment Procedures

The following representative riverflows were used for evaluation based on information furnished by the Rock Island District:

- a.* Maximum regulating weir discharge of 4,200 cfs with normal upper pool el 429.0 and tailwater el 419.9.
- b.* A controlled 10,000-cfs riverflow with normal upper pool el 429.0 and tailwater el 422.4.
- c.* A controlled 15,000-cfs riverflow with normal upper pool el 429.0 and tailwater el 424.6.
- d.* An uncontrolled 20,000-cfs riverflow representing the maximum riverflow at which normal upper pool el 429.0 could be maintained at the dam.
- e.* Bank-full 44,000-cfs riverflow with tailwater el 434.0.
- f.* An intermediate uncontrolled 80,000-cfs riverflow with tailwater el 440.7.
- g.* The maximum navigable riverflow of interest to the Rock Island District, 102,000 cfs with tailwater el 444.0.

The controlled riverflows were reproduced by introducing the proper discharge, setting the tailwater elevation for the discharge, operating the regulating structure at maximum discharge, and manipulating the wickets adjacent to the regulating structure until the required upper pool elevation was obtained. Uncontrolled riverflows were reproduced by introducing the proper discharge with the regulating structure fully open, placing all the dam wickets in

the lowered position, and manipulating the tailgate to obtain the proper tailwater elevation in the lower lock approach. All stages were permitted to stabilize before data were recorded. Velocities were determined by timing the travel of a float submerged to the draft of a loaded barge (9.0 ft) over a measured distance. Current directions were determined by plotting the paths of the floats with respect to ranges established for that purpose. In the interest of clarity, the plots of currents in turbulent areas or where eddies or crosscurrents existed show only the main trends. Spot velocities were obtained using a magnetic velocity meter with a miniature sensor. A model tow representing a 15-barge tow drafting 9 ft was used to evaluate and demonstrate navigation conditions for tows moving through the model reach. With the various plans, the paths of the model tow were recorded with multiple-exposure photographs and model tow behavior was observed in the lock approaches and through the navigation pass.

Base Experiment (Existing Conditions)

Description

Base Experiments were conducted with the model reproducing existing conditions as shown in Figure 3. These experiments both verified the model was reproducing known prototype conditions and provided information and data that could be used to evaluate the effects of proposed modifications on water-surface elevations, current direction and velocities, and navigation conditions. With 30,000-cfs riverflows and above, experiments were conducted with and without the lock gates open as a floodway to pass flow. The riverflows evaluated with the lock gates open were 30,000, 44,000, 80,000, and 102,000 cfs. The uncontrolled 30,000-cfs riverflow represents the minimum riverflow at which the lock is used as a floodway. The following principal features were reproduced or simulated in the model, shown in Figures 3 and 4:

- a.* A navigation lock with clear chamber dimensions of 110 ft wide by 600 ft long located along the right descending bank with upper and lower guide walls.
- b.* A 540-ft-wide wicket dam with a top of sill el 415.0 ft adjacent to the lock consisting of one hundred thirty-four 4-ft-wide wickets. They provide a 540-ft clear width navigation pass with a minimum depth of 15 ft at uncontrolled riverflows.
- c.* A regulating weir adjacent to the right dam abutment consisting of twelve 6-ft-diameter butterfly valves, which regulate the low flows and maintain upper pool elevation.

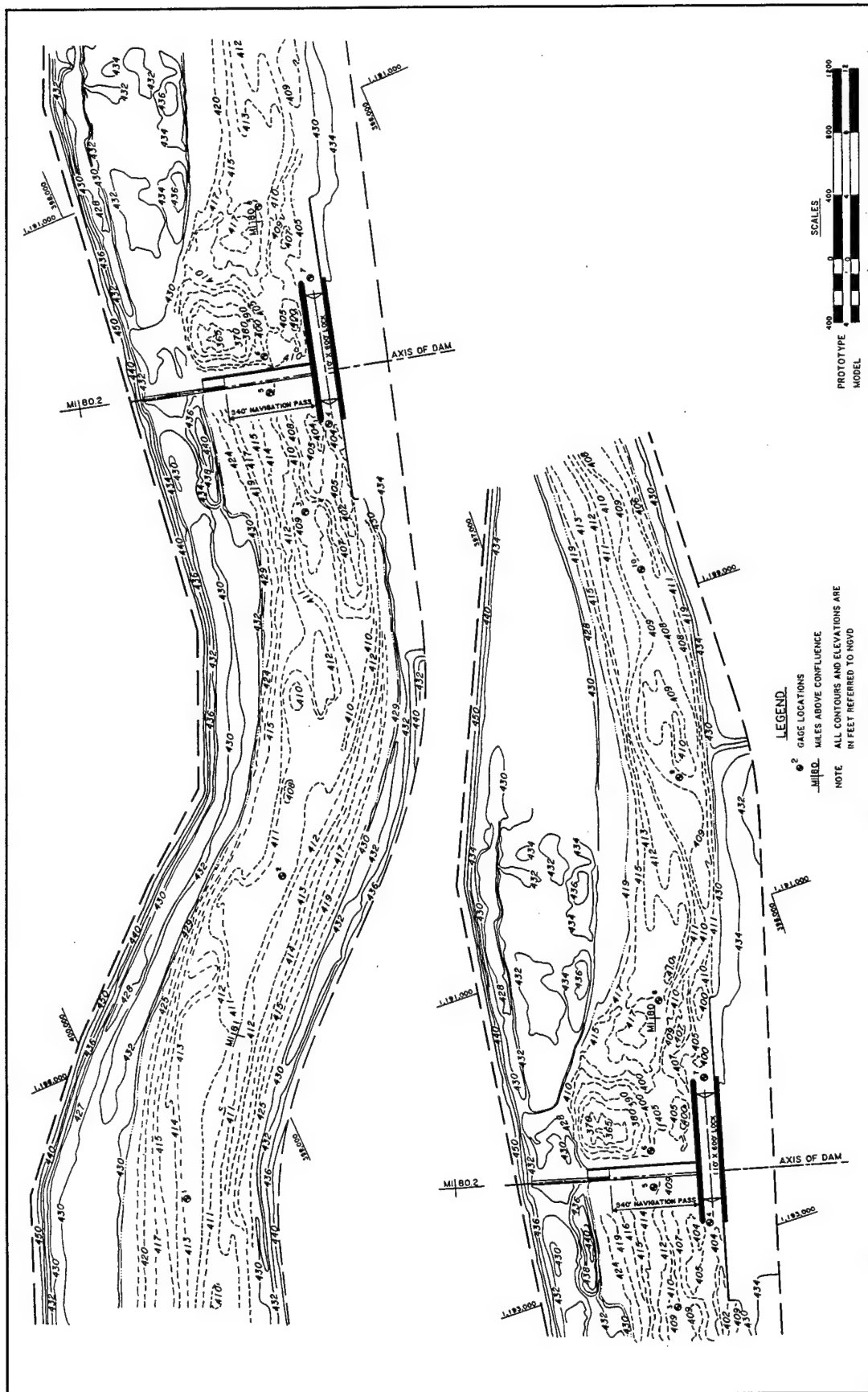
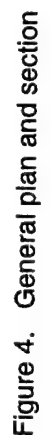


Figure 3. Existing conditions



Results of Base Experiments with lock gates closed

Water-surface elevations. Water-surface elevations obtained with existing conditions (lock gates closed) are shown in Table 1. With uncontrolled riverflows, ranging from 20,000 cfs to 102,000 cfs, the average slope in the model upstream of the dam (gauges 1 to 5) ranged from about 0.1 to 0.3 ft per mile and downstream of the dam (gauges 6 to 10), from about 0.1 to 0.2 ft per mile, respectively. The drop across the wicket dam (gauges 5 and 6) varied from 0.3 to 0.1 ft with riverflows ranging from 20,000 to 102,000 cfs, respectively.

Table 1
Existing Conditions

Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs						
	4.2	10	15	20	44	80	102
1	429.0	429.0	429.1	429.1	434.4	441.1	444.5
2	429.0	429.0	429.0	429.0	434.3	441.0	444.3
3	429.0	429.0	429.0	429.0	434.2	441.0	444.3
4	429.0 ¹	429.0 ¹	429.0 ¹	429.0 ²	434.1	441.0	444.3
5	429.0	429.0	429.0	428.9	434.1	440.8	444.2
6	420.0	422.2	424.5	424.5	434.0	440.7	444.1
7	419.9 ¹	422.4 ¹	424.6 ¹	424.6 ¹	434.0 ¹	440.7 ¹	444.0 ¹
8	419.8	422.4	424.6	424.6	434.0	440.6	444.0
9	419.8 ¹	422.3 ¹	424.5 ¹	424.5	433.8	440.6	444.0
10	419.8	422.3	424.4	424.4	433.7	440.4	443.8

¹ Controlled to elevation from tailwater rating curve furnished by District.
² Controlled to elevation furnished by District.

Current directions and velocities. Current directions and velocities obtained with existing conditions and the lock gates closed are shown in Plates 1-8. These data indicate the currents through the model reach were generally parallel with the right descending bank except in the vicinity of the structures. The currents moved away from the right bank near the upstream end of the upper guide wall and across the lock approach toward the dam. The currents immediately downstream of the dam were directed across the lower lock approach but were generally parallel to the right bank downstream of the lower guide wall. With controlled 4,200- to 15,000-cfs riverflows (Plates 1-3) the alignment of the currents approaching the lock was generally parallel to the right descending bank except for the crosscurrents near the upper guide wall. The current velocities near the upper guide wall ranged from less than 0.5 fps with the 4,200-cfs to 1.5 fps with the 15,000-cfs riverflow. The alignment of currents downstream of the dam was directed across the lower lock approach with the maximum velocity of 1.3 fps occurring with the 10,000-cfs riverflow. The 20,000-cfs riverflow was

evaluated with 100 ft of wickets raised (Plate 4) and with all wickets lowered (Plate 5). By raising 100 ft of the wickets the crosscurrents near the upper guide wall and velocities through the navigation pass were increased, compared to all wickets lowered. With all wickets lowered and 20,000- to 102,000-cfs riverflows, the alignment of the currents upstream of the dam was generally parallel to the right bank with a slight curve toward the left bank near the navigation pass, generally straight through the pass, and turned toward the right bank downstream of the pass. A slow eddy formed in the lower lock approach. The average velocities across the channel varied from 1.9 to 4.4 fps near the upstream end of the upper guide wall, 2.6 to 5.0 fps through the navigation pass, and 2.5 to 3.8 fps near the downstream end of the lower guide wall with the 20,000- and 102,000-cfs riverflows, respectively. A maximum velocity of 5.6 fps occurred through the navigation pass with the 102,000-cfs riverflow.

Navigation conditions. The lock is on the outside of a bend and provides satisfactory navigation conditions for downbound tows with the lower riverflows. Downbound tows could align with the upper guide wall and enter the lock chamber without difficulties. However, as the riverflow increased to 15,000 cfs and the crosscurrents increased, there was a tendency for the tow to move away from the guide wall as it reduced speed to align with the lock (Photo 1). Considerable maneuvering or some type of assistance could be required for the tow to align with the guide wall and move into the lock chamber. As the riverflow increased to 20,000 cfs, all wicket gates were lowered and tows could bypass the lock by moving through the 540-ft-wide navigation pass. Downbound tows could drive the bend upstream of the dam, align with the navigation pass, and drive through the pass without any major difficulties (Photos 2-4). Model experiments did not indicate any difficulties for tows entering or exiting the lower lock approach with controlled riverflows (Photos 5 and 6). With open 20,000-cfs riverflows and above, upbound tows required considerable maneuvering to move through the navigation pass due to changes in current alignment upstream of the dam to a short distance downstream of the dam. The tow navigated the reach like a reverse bend; therefore, it occupied several hundred feet of the pass (Photos 7-9). The normal sailing line through the navigation pass for upbound tows navigating the weir with uncontrolled riverflows tends to be approximately 200 ft riverward of the lock. Tows entering the navigation pass riverward of this point require more maneuvering and occupy a greater portion of the channel width.

Meter velocities. Point velocity measurements were made near the riverbed immediately upstream and downstream of the regulating structure and wicket dam for comparison with the proposed plans (Plates 9 and 10). With the 15,000-cfs riverflow, when the flow was concentrated through the regulating structure and the wickets adjacent to the structure (normal operation procedure), there were high-velocity currents immediately downstream of the structure with some eddying. These velocities were in the vicinity of the large scour hole that is evident in the prototype. With the 20,000-cfs riverflow and the wickets down, the flow was more evenly distributed across the structure. The average velocities upstream and downstream of the dam were about 2.5 fps.

Results of Base Experiments with lock gates open

Water-surface elevations. Water-surface elevations obtained with existing conditions and the lock used as a floodway are shown in Table 2. Water-surface elevations decreased about 0.1 ft in the upper pool with the 44,000- and 80,000-cfs riverflows and showed no appreciable change with the 102,000-cfs riverflow. There was no appreciable change in the drop across the wicket dam (gauges 6 and 7) compared with the Base Experiment with the lock closed. With the 30,000-cfs riverflow, the average slope in the model was about 0.2 ft per mile upstream of the dam (gauges 1 to 5) and 0.1 ft per mile downstream of the dam (gauges 6 to 10) with the drop across the dam about 0.1 ft.

Table 2				
Existing Conditions, Lock Open as Floodway				
Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs			
	30	44	80	102
1	433.2	434.3	441.1	444.5
2	433.1	434.2	440.9	444.3
3	433.0	434.1	440.9	444.3
4	433.0	434.0	440.8	444.2
5	433.0	434.1	440.8	444.2
6	432.9	434.0	440.7	444.1
7	432.9	433.9	440.7	444.0
8	432.9	433.9	440.6	444.1
9	432.8	433.7	440.5	444.0
10	432.8 ¹	433.7 ¹	440.4 ¹	444.8 ¹
¹ Controlled elevation.				

Current directions and velocities. Current directions and velocities, obtained with existing conditions and the lock used as a floodway (Plates 11-14), indicated a significant change in the current alignment in the vicinity of the lock and the wicket dam with the 44,000-, 80,000-, and 102,000-cfs riverflows. The eddy that formed in the lower lock approach with the lock closed was eliminated by the flow through the lock. The velocities through the navigation pass decreased about 0.8 and 0.5 fps with the 44,000- and 80,000-cfs riverflows, respectively, and remained about the same with the 102,000-cfs riverflow. With the 30,000-cfs riverflow (Plate 11), the current velocities across the channel averaged about 2.4 fps near the end of the upper guide wall, 2.3 fps through the navigation pass, and 2.5 fps near the end of the lower guide wall.

Navigation conditions. Opening the lock as a floodway improved navigation conditions for tows using the navigation pass with 30,000-cfs riverflows and above. Due to the improved alignment of the currents in the vicinity of the structures, upbound tows required less maneuvering and occupied less channel width moving through the navigation pass.

Plan A

Description

Plan A (Figures 5 and 6) was the same as existing conditions except for two 60-ft-wide by 24-ft-high submersible tainter gates with three 8-ft-wide piers placed adjacent to the lock (Figure 7). The two tainter gates were designed to control the pool to open-pass conditions. Therefore, all flow up to 20,000-cfs riverflow (open pass condition) was passed through the tainter gates except for leakage from the wickets and flow through the regulating structure (which remained in operation to facilitate upper pool maintenance). The tainter gate structure replaced 144 ft of the wicket dam, reducing the navigation pass from 540.0 ft to 396.0 ft. With 30,000-cfs riverflows and above, experiments were conducted with and without the lock gates open as a floodway to pass flow. The riverflows evaluated with the lock gates open were 30,000, 44,000, 80,000, and 102,000 cfs. The 30,000-cfs uncontrolled riverflow represents the minimum riverflow at which the lock is used as a floodway.

Results with lock gates closed

Water-surface elevations. Adding two tainter gates to Plan A had little or no effect on water-surface elevations (Table 3). The average slope through the model was generally the same as with the Base Experiments. With the 15,000- and 20,000-cfs riverflows, the water surface immediately downstream of the dam (gauge 6) increased 0.1 ft and decreased about 0.1 ft with the 102,000-cfs riverflow. The drop across the dam (gauges 5 to 6) decreased about 0.1 ft with the 20,000-cfs riverflow and increased 0.1 ft with the 102,000-cfs riverflow.

Current direction and velocities. The current direction and velocities shown in Plate 15 and the surface current patterns shown in Photos 10 and 11 indicate a considerable change in the current alignment upstream and downstream of the weir with the 15,000-cfs riverflow. The flow was concentrated through the tainter gates, along the riverside lock wall, and across the lower lock approach. The maximum velocity of currents moving across the lower lock approach was about 3.2 fps. The velocities upstream of the dam were generally the same as the base conditions. Data shown in Plates 16-19 indicated no significant changes in current alignment or velocities approaching the navigation pass with uncontrolled 20,000-cfs riverflow and above.

Navigation conditions. With controlled riverflows, there was a slight improvement in navigation conditions for downbound tows approaching the guide wall and aligning with the lock chamber (Photo 12). The crosscurrents near the upper guide wall were reduced somewhat with the 15,000-cfs riverflow. However, downbound tows approaching the lock several hundred feet riverward of the right bank would move away from the guide wall and could require considerable maneuvering or some type of assistance to align with and enter the lock chamber (Photo 13). There were no major difficulties for upbound tows

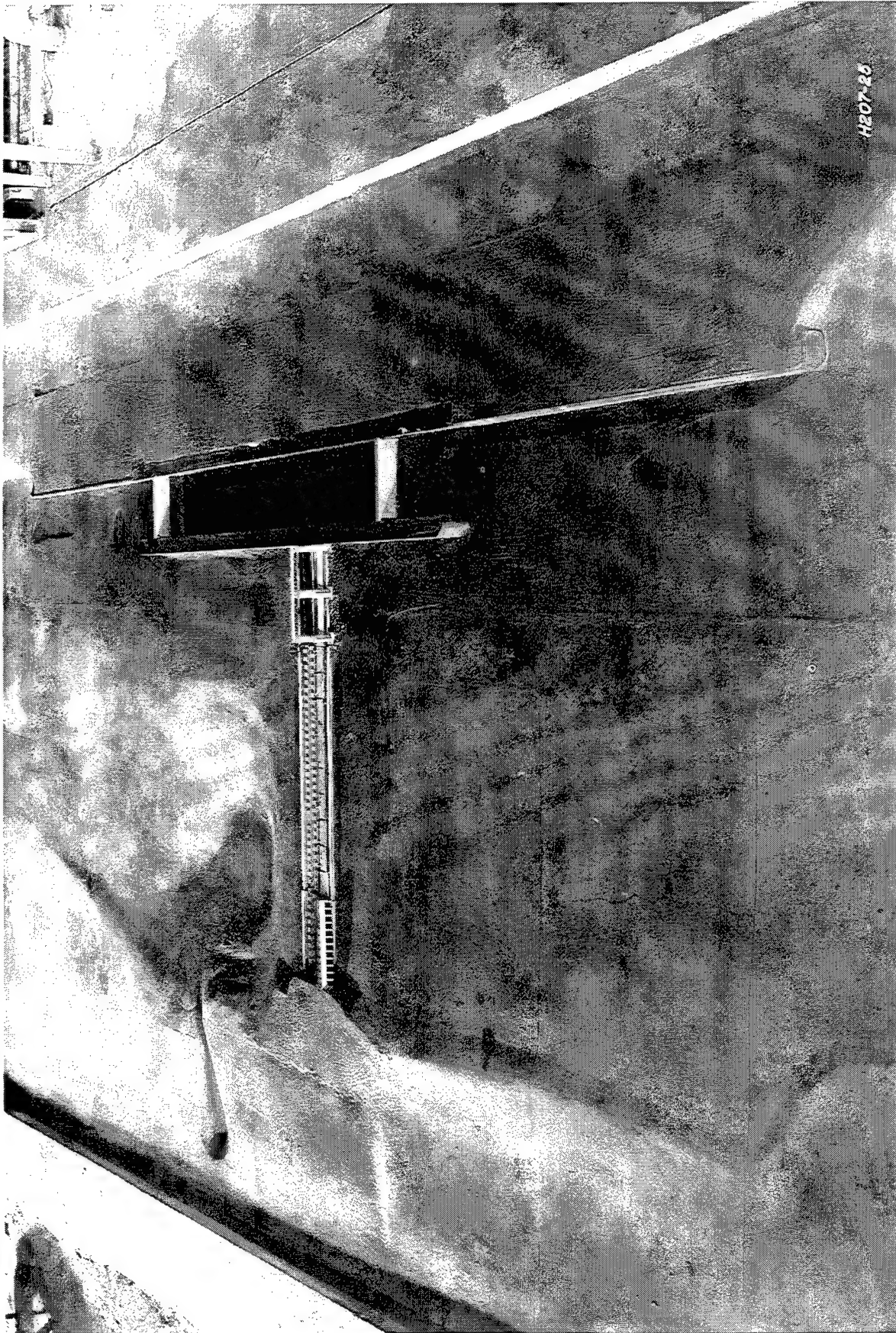


Figure 5. Plan A structures looking downstream

Table 3					
Plan A					
Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs				
	15	20	44	80	102
1	429.1	429.1	434.4	441.1	444.5
2	429.0	429.0	434.3	441.0	444.3
3	429.0	429.0	434.2	441.0	444.3
4	429.0 ¹	429.0	434.1	441.0	444.3
5	429.0	428.9	434.1	440.9	444.2
6	424.6	428.7	434.0	440.8	444.0
7	424.6	428.7	434.0	440.7	444.0
8	424.6	428.7	433.9	440.7	444.0
9	424.5	428.7	433.8	440.6	444.0
10	424.4 ¹	428.6 ¹	433.7 ¹	440.4 ¹	444.8 ¹
¹ Controlled elevation.					

leaving the lock (Photo 14). With uncontrolled 20,000-cfs riverflow and above, tows navigated over the wicket dam. With the 20,000- and 44,000-cfs riverflows, the reduced width of the navigation pass (540 ft compared to 398 ft) and the encroachment of the tainter gates on the normal sailing line created potentially hazardous navigation conditions. Downbound tows tended to approach the navigation pass at an angle, driving toward the center of the pass due to the left bank configuration upstream of the navigation pass, the alignment of the currents approaching the navigation pass, and the encroachment of the tainter gates. There was a tendency for the tow to slide toward the tainter gates as it approached the pass with the possibility of striking the riverside pier (Photo 15). There was also a tendency for the stern of the tow to rotate toward the regulating structure as it moved through the pass with the possibility of grounding on the structure (Photo 16). As the riverflow increased to 102,000 cfs, the tendency for downbound tows to push into the pier was decreased. The increased navigation channel width upstream and downstream of the navigation pass and the alignment of the currents approaching the pass allowed the tow to make a better approach to the pass (Photo 17). Tows could enter and exit the lower lock approach with the 15,000-cfs riverflow without major difficulties. With uncontrolled riverflows, upbound tows tend to move through the navigation pass riverward of the normal sailing line due to location of the tainter gates; therefore, they require more maneuvering and occupy a greater width of the navigation pass compared to the Base Experiment (Photos 18-20).

Meter velocities. Plates 20 and 21 show meter velocities made near the riverbed immediately upstream and downstream of the tainter gates, wicket dam, and the regulating structure. These data indicated an increase in the velocity of the currents upstream and downstream of the tainter gates with the 15,000- and 20,000-cfs riverflows. The maximum velocities upstream and downstream of the

tainter gates occurred with the 15,000-cfs riverflow when the largest percentage of the flow passed through the tainter gates. The maximum velocities ranged from about 2.8 fps upstream of the gates to 6.0 fps downstream of the gates. The high velocities observed downstream of the regulating structure during Base Experiments were eliminated. The maximum velocity downstream of the regulating structure was about 1.7 fps. With the 20,000-cfs riverflow and the wickets down, the flow was more evenly distributed across the structure. However, due to the lower crest elevation of the tainter gates, there was some concentration of flow through the gates. The maximum velocities upstream and downstream of the tainter gates were about 3.0 and 2.1 fps, respectively. This indicated the scour pattern downstream of the dam could change considerably, with the scour hole downstream of the regulating structure filling in with deposition.

Results with lock gates open

Opening the lock for a floodway had little or no effect on water-surface elevations (Table 4). There was no appreciable change in the average slope through the model with the riverflows evaluated.

Table 4				
Plan A, Lock Open As Floodway				
Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs			
	30	40	80	102
1	433.2	434.4	441.1	444.5
2	433.2	434.3	441.0	444.3
3	433.2	434.2	441.0	444.2
4	433.1	434.2	441.0	444.2
5	433.1	434.1	440.9	444.2
6	433.1	433.9	440.8	444.1
7	433.0	433.9	440.8	444.1
8	433.0	433.8	440.7	444.0
9	432.9	433.8	440.6	444.0
10	432.8 ¹	433.7	440.4	443.8 ¹
¹ Controlled elevation.				

Current direction and velocities. Current direction and velocities data obtained with the lock gate open indicated a significant change in the current alignment and a slight decrease in velocities through the navigation pass ranging from 0.8 fps with 44,000-cfs riverflow to 0.4 fps with 102,000-cfs riverflow (Plates 22-25). The eddy that formed in the lower lock approach with the lock closed was eliminated by flow passing through the lock. With the 30,000-cfs riverflow (Plate 22), the current velocities across the channel averaged about 2.7 fps near the end of the upper guide wall, 3.0 fps through the navigation pass,

and 2.9 fps near the end of the lower guide wall. The maximum velocity through the navigation pass was 5.2 fps and occurred with the 102,000-cfs riverflow.

Navigation conditions. Opening the lock as a floodway slightly improved the approach conditions to the wicket dam. However, the encroachment of the tainter gate structure on the normal sailing line created potentially hazardous navigation conditions similar to Plan A with the lock gates closed.

Plan B

Description

Plan B (Figures 8-10) was the same as the existing conditions except for a 100-ft-wide tainter gate structure with a crest el of 415.5 ft placed adjacent to the lock. The tainter gate structure consisted of one 84-ft-wide submersible tainter gate and two 8-ft-wide piers. With the pier recesses, an effective opening of 76 feet is provided. The tainter gate structure replaced 100 ft of the existing wicket dam, reducing the navigation pass from 540 ft to 440 ft. The regulating structure adjacent to the left bank remained in operation to facilitate upper pool maintenance. With 30,000-cfs riverflows and above, the lock gates were opened and the lock used as a floodway; therefore, comparisons are to the Base Experiment with the open lock as a floodway.

Results

Water-surface elevations. The Plan B addition of the 100-ft-wide tainter gate structure had little or no effect on water-surface elevations (Table 5). The average slope through the model did not change appreciably with any riverflows evaluated. With uncontrolled riverflows, ranging from 20,000 cfs to 102,000 cfs, the average slope in the model upstream of the dam (gauges 1 to 5) ranged about 0.1 to 0.4 ft per mile and downstream of the dam (gauges 6 to 10) ranged about 0.1 to 0.3 ft per mile. The drop across the dam (gauges 5 and 6) varied from 0.3 ft to less than 0.1 ft.

Current directions and velocities. The current directions and velocities shown in Plate 26 and the surface current patterns shown in Photos 21 and 22 indicated a considerable change in the current alignment upstream and downstream of the dam with the 10,000-cfs riverflow compared to Base Experiments; however, the currents were similar to Plan A. The flow was concentrated through the tainter gate, along the riverside lock wall, and across the lower lock approach. The maximum velocity of currents moving across the lower lock approach was about 2.1 fps. The velocities upstream of the dam were generally the same as base conditions. The current direction and velocity data





Figure 10. Plan B tainter gate location

shown in Plates 27-31 and the surface current patterns shown in Photos 23-26 indicated no significant changes in current alignment approaching the navigation pass and a slight increase in velocities through the navigation pass with uncontrolled 20,000-cfs riverflows and above. Velocities across the channel averaged 2.0 fps near the end of the upper guide wall, 2.9 fps through the navigation pass, and 2.4 fps near the end of the lower guide wall with the 20,000-cfs riverflow and averaged 4.7 fps, 4.9 fps, and 4.3 fps, respectively, with the 102,000-cfs riverflow.

Navigation conditions. With controlled riverflows, the model indicated no significant difference in navigation conditions for tows entering or exiting the lock approaches compared to the Base Experiment (Photos 27-31). The crosscurrents near the upper guide wall observed during the Base Experiment were reduced somewhat with the 10,000-cfs riverflow; however, considerable

Table 5					
Plan B					
Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs				
	20	30¹	44¹	80¹	102¹
1	429.1	433.2	434.4	441.2	444.5
2	429.0	433.1	434.3	441.0	444.3
3	429.0	433.0	434.2	440.9	444.3
4	429.0	433.0	434.1	440.8	444.2
5	429.0	433.0	434.1	440.8	444.2
6	428.7	433.0	434.0	440.8	444.1
7	428.7	433.0	434.0	440.7	444.1
8	428.7	432.9	434.0	440.6	444.1
9	428.6	432.8	433.8	440.6	444.0
10	428.6 ²	432.0 ²	433.7 ²	440.4 ²	443.8 ²
¹ Lock open as floodway.					
² Controlled elevation.					

maneuvering or some assistance could be required for downbound tows to enter the lock. With 20,000-cfs riverflows and above, the wickets would be lowered and tows could run the navigation pass. Downbound tows would tend to approach the navigation pass at an angle driving toward the center of the pass due to channel configuration upstream of the dam, the alignment of the currents approaching the navigation pass, and the encroachment of the tainter gate structure (Photos 32-36). With an uncontrolled 20,000-cfs riverflow, there was a tendency for the tow to slide toward the tainter gate structure; however, there appeared sufficient clearance for the tow to safely navigate the pass (Photo 32). An upbound tow would occupy the major portion of the navigation pass and require considerable maneuvering to navigate around the tainter gate structure (Photo 36). When the lock was opened as a floodway with 30,000-cfs riverflows and above, the amount of maneuvering required to navigate through the pass was reduced considerably (Photos 37-39).

Meter velocities. Plates 32 and 33 show meter velocity measurements made near the riverbed immediately upstream and downstream of the tainter gates, wicket dam, and the regulating structure. These data indicated an increase in the velocity of the currents upstream and downstream of the tainter gates with the 15,000- and 20,000-cfs riverflows. The maximum velocities upstream and downstream of the tainter gates occurred with the 15,000-cfs riverflow when the largest percentage of the flow passed through the tainter gates. The maximum velocities ranged from about 4.0 fps upstream of the gates to 9.2 fps downstream of the gates. The high velocities observed downstream of the regulating structure during Base Experiments were reduced considerably. The maximum velocity downstream of the regulating structure was about 3.0 fps. With the 20,000-cfs riverflow and the wickets down, the flow was more evenly distributed across the structure. However, due to the lower crest elevation of the tainter gates, there

was some concentration of flow through the gates. The maximum velocities upstream and downstream of the tainter gates were about 2.7 and 1.9 fps, respectively. This indicates the scour pattern downstream of the dam could change considerably, with the scour hole downstream of the regulating structure filling in with deposition.

Plan C

Description

Plan C (Figures 11 and 12) was the same as Plan B except the tainter gate was moved upstream 90 ft. The tainter gate and piers of Plan B were constructed in place of a section of the wicket dam sill. This plan required placing the cofferdam sheet piling on the wicket sill and extending it upstream and downstream of the existing sill. Any cofferdam design for Plan B was considered at high risk for a cofferdam failure. Therefore, to obtain a positive cutoff all around the construction area, Plan C was developed moving the gate and piers of Plan B upstream of the wicket sill. The gate and pier dimensions for Plan C remained the same as Plan B except that the riverward pier was extended to form an abutment of the remaining wickets. The bullnose of the piers for Plan C extended 104 ft upstream of the existing wicket sill.

Results

Water-surface elevations. Table 6 indicated no significant change in water-surface slope compared to Plan B.

Current direction and velocities. Data shown in Plates 34-39 indicated the current patterns are generally the same as Plan B except for minor changes immediately upstream and downstream of the tainter gate. With a controlled 15,000-cfs riverflow, the flow was concentrated through the tainter gate, along the riverside lock wall, and across the lower lock approach (Plate 34, Photos 40 and 41). The maximum current velocity moving across the upper lock approach was about 1.5 fps while the maximum current velocity moving across the lower lock approach was about 3.7 fps. With uncontrolled 20,000-cfs riverflows and above, the velocities upstream of the dam were generally the same as base conditions. The current direction and velocity data shown in Plates 34-39 and the surface current patterns shown in Photos 42-45 indicated no significant changes in current alignment approaching the navigation pass and a slight increase in velocities through the navigation pass. Velocities across the channel averaged 1.8 fps near the end of the upper guide wall, 1.8 fps approaching the navigation pass, and 2.1 fps near the end of the lower guide wall with the 20,000-cfs riverflow and averaged 4.4 fps, 4.5 fps, and 4.4 fps, respectively, with the 102,000-cfs riverflow.

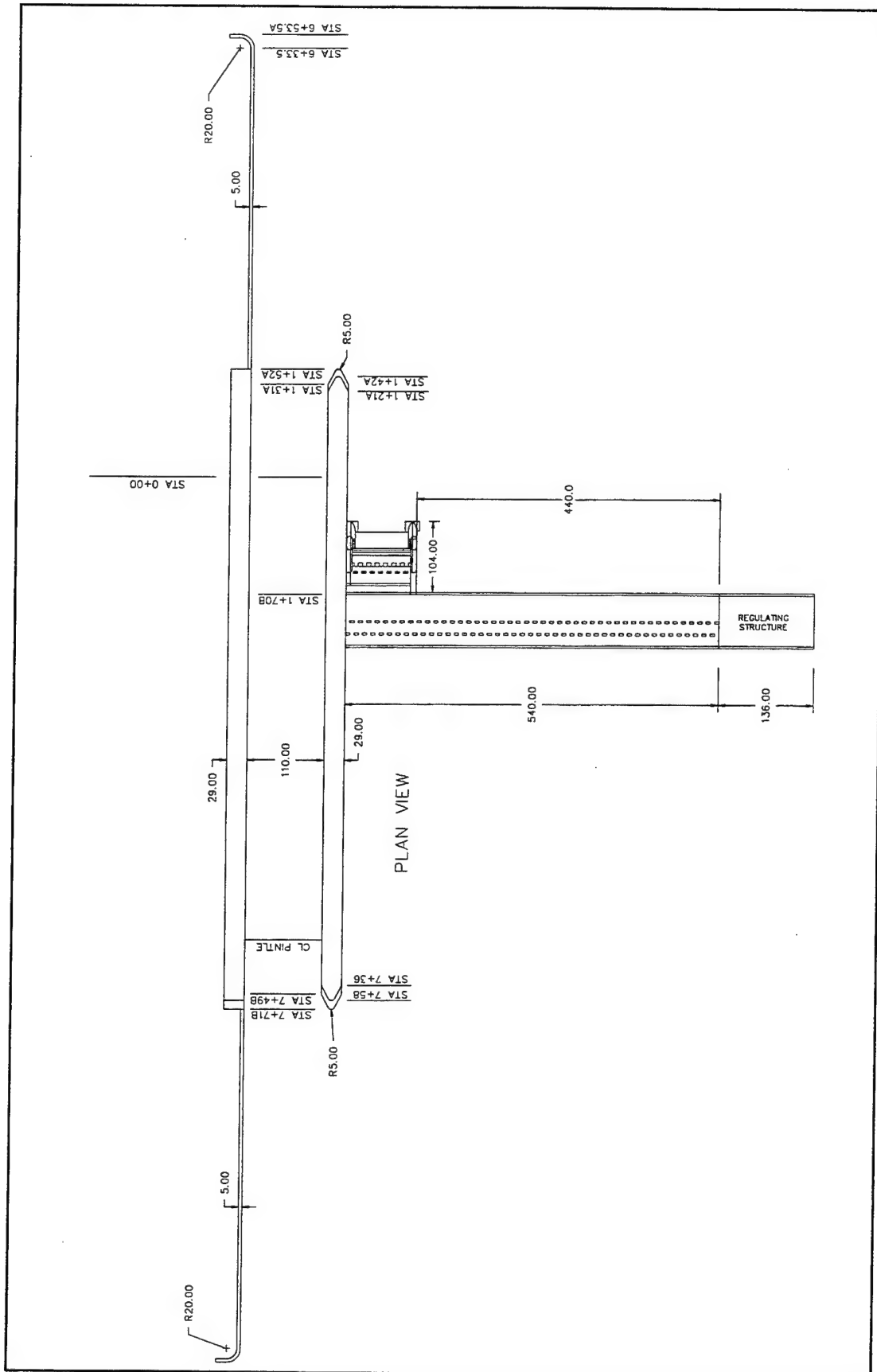


Figure 11. Plan C layout



Figure 12. Plan C tainter gate location

Navigation conditions. Conditions with Plan C were generally the same as Plan B. With controlled riverflows, the model indicated no significant difference in navigation conditions for tows entering or exiting the lock approaches compared to the Base Experiment (Photos 46-49). The crosscurrents near the upper guide wall that were observed during the Base Experiment were reduced somewhat with the 15,000-cfs riverflow; however, considerable maneuvering or some assistance could be required for downbound tows to enter the lock. With 20,000-cfs riverflows and above, the wickets would be lowered and tows could run the navigation pass. Downbound tows tended to approach the navigation pass at an angle driving toward the center of the pass due to the channel configuration upstream of the dam, the alignment of the currents approaching the navigation pass, and the encroachment of the tainter gate structure (Photos 50-58). With an uncontrolled 20,000-cfs riverflow and the lock closed, there was a tendency for a downbound tow to slide toward the tainter gate structure;

Table 6
Plan C

Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs				
	20	30 ¹	44 ¹	80 ¹	102 ¹
1	429.1	433.2	434.4	441.2	444.5
2	429.0	433.1	434.3	441.0	444.3
3	429.0	433.1	434.2	440.9	444.3
4	429.0	433.0	434.1	440.9	444.2
5	429.0	433.0	434.1	440.8	444.2
6	428.7	433.0	434.0	440.8	444.1
7	428.7	433.0	434.0	440.7	444.1
8	428.7	432.9	434.0	440.6	444.1
9	428.6	432.8	433.8	440.6	444.0
10	428.6 ²	432.8 ²	433.7 ²	440.4 ²	443.8 ²

¹ Lock open as floodway.

² Controlled elevation.

however, there appeared sufficient clearance for the tow to safely navigate the pass (Photo 50). An upbound tow would occupy the major portion of the navigation pass and require considerable maneuvering to navigate around the tainter gate structure (Photo 51). Opening the lock as a floodway with the 20,000-cfs riverflow improved navigation conditions for both upbound and downbound tows (Photos 52-54). With 30,000- and 44,000-cfs riverflows, a downbound tow driving the bend immediately upstream of the structure would tend to crowd the riverward pier of the tainter gate (Photo 55). Downbound tows may begin flanking the bend to better align with the navigation pass. When riverflow increases to 102,000 cfs, downbound tows can run the point bar of the bend and align with the navigation pass farther upstream (Photo 56). With 30,000-cfs riverflows and above and the lock open as a floodway, upbound tows could move through the navigation pass with minimum maneuvering (Photos 57 and 58).

Plan C Cofferdam

Description

A 112-ft-wide by 118-ft-long cofferdam with top elevation of 430 was placed adjacent to the lock and upstream of the existing wicket dam to encompass the construction area for the new tainter gate (Figure 13).

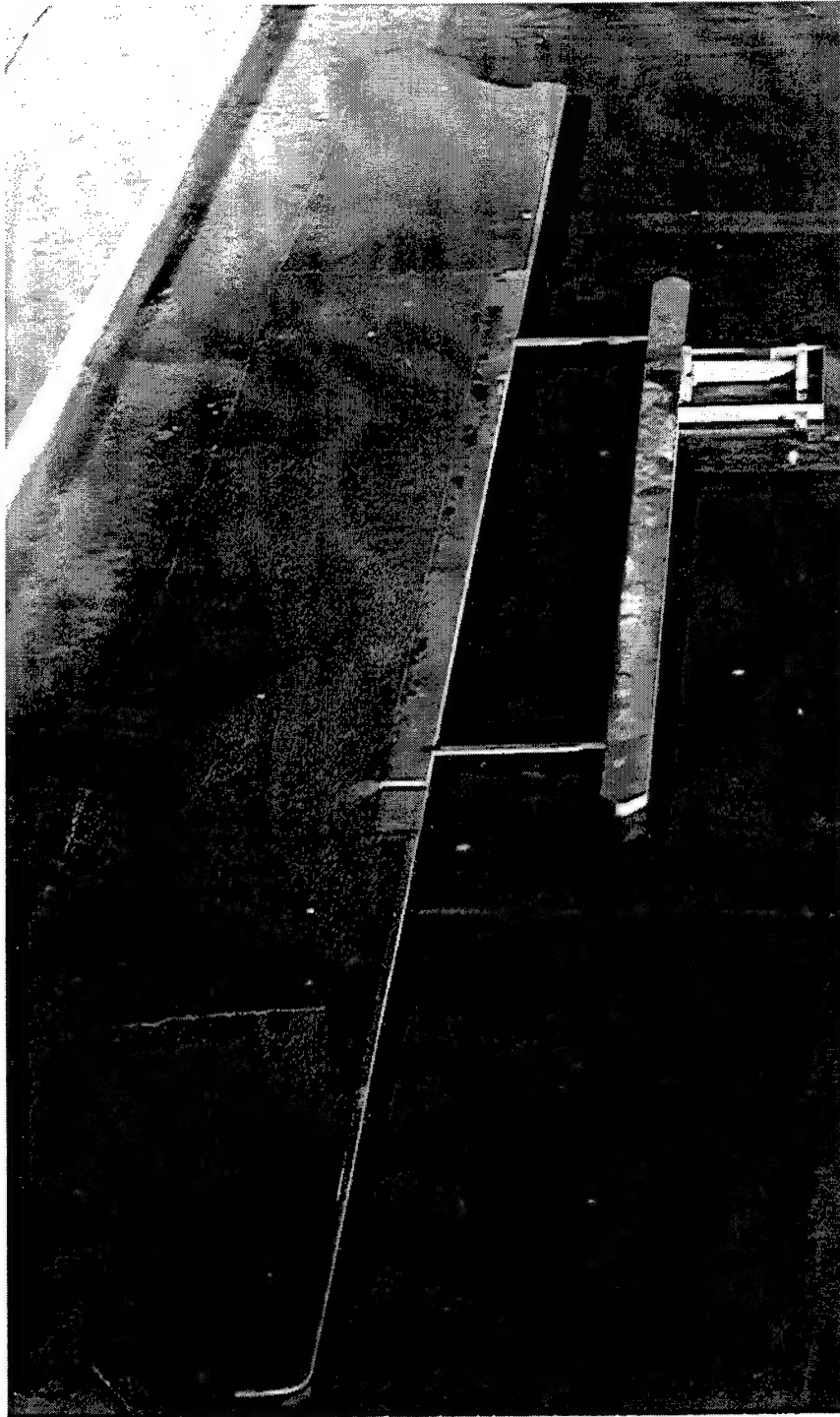


Figure 13. Plan C cofferdam

Results

Water-surface elevations. Table 7 indicated no appreciable change in water-surface slope compared to Plan C.

Table 7 Plan C Cofferdam					
Gauge No.	Water-Surface Elevations for Discharge, 1,000 cfs				
	20	30 ¹	44 ¹	80 ¹	102 ¹
1	429.1	433.2	434.4	441.2	444.5
2	429.0	433.1	434.3	441.0	444.3
3	429.0	433.1	434.2	440.9	444.3
4	429.0	433.0	434.1	440.8	444.2
5	429.0	433.0	434.1	440.8	444.2
6	428.7	433.0	434.0	440.8	444.1
7	428.7	433.0	434.0	440.7	444.1
8	428.7	432.9	434.0	440.6	444.1
9	428.6	432.8	433.8	440.6	444.0
10	428.6 ²	432.8 ²	433.7 ²	440.4	443.8 ²
¹ Lock open as floodway.					
² Controlled elevation.					

Current direction and velocities data. Plates 40-44 and Photos 59-62 indicated that current patterns are generally the same as Plan C except in the immediate vicinity of the structures. The cofferdam reduced the flow area of the wicket dam by 118 ft and increased the velocity and angle of the currents through the navigation pass. The velocity of the currents through the navigation pass averaged 3.4 ft and 4.9 fps with the 20,000-cfs and 102,000-cfs riverflows, respectively.

Navigation conditions. Conditions approaching the structures were generally the same as with Plan C, but more maneuvering was required to move through the navigation pass. The encroachment of the cofferdam on the navigation pass reduced the effective width of the pass from 540 ft to 422 ft. With a 20,000-cfs riverflow and the lock closed as a floodway, the downbound tow driving the bend upstream of the structure would tend to slide as it approached the navigation pass and crowd the cofferdam (Photo 63). At this point tows may elect to flank the bend for safety reasons. An upbound tow required considerable maneuvering to navigate around the cofferdam (Photo 64). When the lock was opened as a floodway, navigation conditions for downbound and upbound tows improved (Photos 65 and 66). With 30,000-cfs and 44,000-cfs riverflows, the downbound tow tended to slide toward and crowd the cofferdam as it approached the navigation pass (Photo 67). However, by flanking the bend upstream of the structures, downbound tows could align with the navigation pass farther upstream and safely move past the cofferdam. As riverflow increased and the navigation

channel width increased in the bend upstream of the structures, a downbound tow could drive closer to the left descending bank and align with the navigation pass farther upstream (Photo 68). An upbound tow required considerable maneuvering to navigate around the cofferdam due to the angle of the currents moving through the navigation pass (Photo 69). Under some conditions a tow could be pushed into the regulating structure as it turns around the cofferdam and back into the navigation channel. With 30,000-cfs riverflows and above, upbound tows could move through the navigation pass with reduced maneuvering (Photos 69 and 70).

4 Discussion of Results and Conclusions

Limitations of Model Results

Analysis of this investigation's results is based on a study of the following: the effects of various plans and modifications on water-surface elevations and current directions and velocities; and the effects of the resulting currents on model towboat and tow behavior. In evaluating experiment results, the following should be taken into consideration: small changes in current directions and velocities are not necessarily changes produced by a modification in the plan since several floats introduced at the same point may follow a different path and move at somewhat different velocities due to pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to the depth of a loaded barge (9 ft prototype) and are more indicative of currents affecting the behavior of tows than those shown in the photographs, which indicate the movement of confetti on the water surface and could be affected by surface tension.

The small scale of the model made it difficult to accurately reproduce the hydraulic characteristics of the prototype structures or to measure water-surface elevation with an accuracy greater than about ± 0.1 ft prototype. Also, current directions and velocities were based on steady flows and would be somewhat different with varying flows. The model was a fixed-bed type and not designed to reproduce overall sediment movement that might occur in the prototype with the various plans. Therefore, changes in channel configuration resulting from scouring and deposition and any resulting changes in current directions and velocities were not evaluated.

Summary of Results and Conclusions

The following results and conclusions were developed during the investigation:

- a. The proposed tainter gates of Plan A would decrease the outdraft along the upper guide wall with controlled riverflows and slightly improve navigation conditions into the upper lock approach.
- b. The proposed tainter gates of Plan A would reduce the width of the navigation pass by 27 percent (from 540 ft to 396 ft) and could be hazardous for navigation, especially with the 20,000- and 44,000-cfs riverflows.
- c. With all plans evaluated, opening the lock as a floodway improved the current alignment in the vicinity of the structures, eliminated the eddy in the lower lock approach, reduced the velocities through the navigation pass slightly, and reduced the amount of maneuvering required for tows to navigate the reach.
- d. Plan B's proposed tainter gate structure tended to decrease the outdraft along the upper guide wall with controlled riverflows and slightly improve navigation conditions into the upper lock approach.
- e. With Plan B and 30,000- and 44,000-cfs riverflows, a downbound tow driving the bend immediately upstream of the structure would tend to crowd the riverward pier of the tainter gate. Downbound tows may begin flanking the bend to better align with the navigation pass.
- f. Although the proposed tainter gate structure of Plan B reduced the existing width of the navigation pass by 18.5 percent (from 540 ft to 440 ft), there appeared to be sufficient width to provide satisfactory clearance for tows to safely maneuver through the reach.
- g. Plan C moved the tainter gate structure upstream of the existing wicket dam and provided a better design for construction of the structure.
- h. Navigation conditions with Plan C were generally the same as Plan B and provided satisfactory navigation conditions through the reach. Moving the proposed tainter gate structure upstream of the wicket dam did not adversely affect navigation conditions through the reach.
- i. The cofferdam evaluated for construction of the proposed tainter gate structure provided sufficient navigation pass width for tows to safely maneuver through the reach. However, with higher riverflows considerable maneuvering could be required and proper caution should be taken.

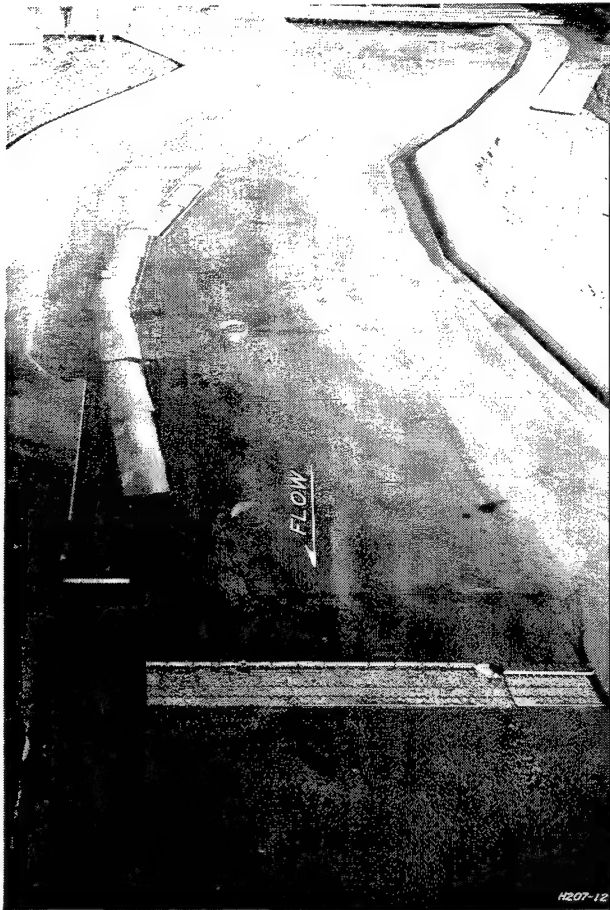
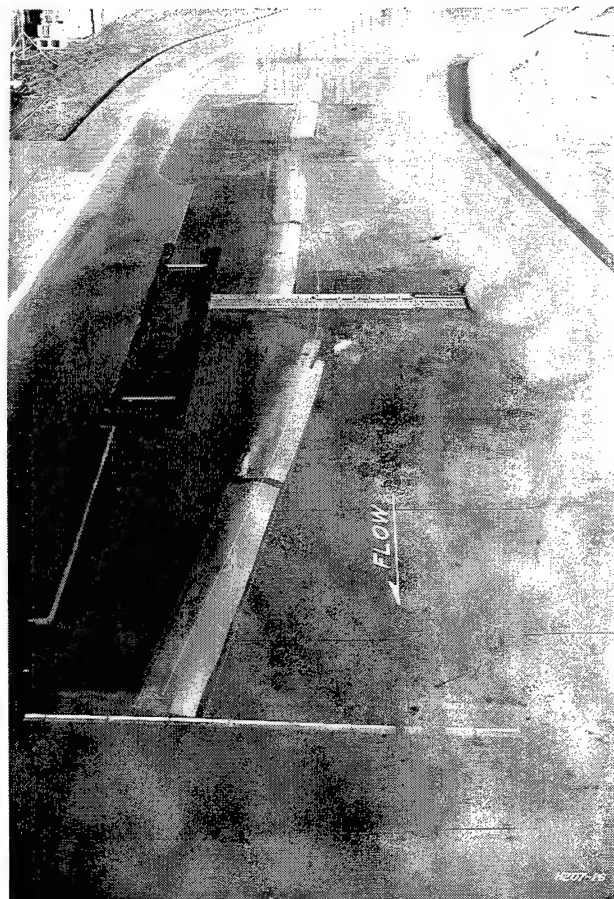


Photo 1. Base Experiment, existing conditions; looking upstream; discharge 15,000 cfs; showing path of downbound tow approaching lock

Photo 2. Base Experiment, existing conditions; looking upstream; discharge 20,000 cfs; showing path of downbound tow navigating the reach



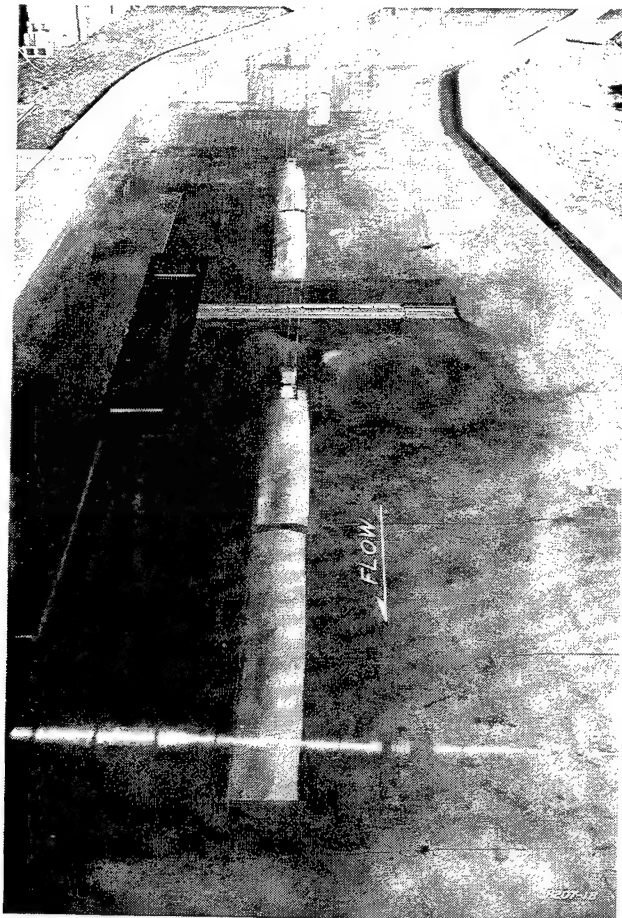


Photo 3. Base Experiment, existing conditions; looking upstream; discharge 44,000 cfs; showing path of downbound tow navigating the reach

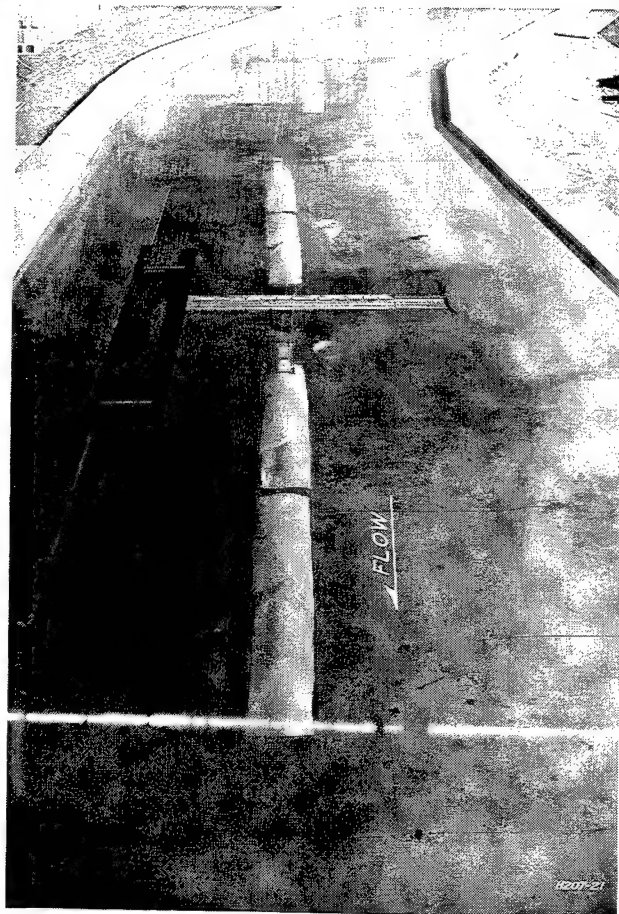


Photo 4. Base Experiment, existing conditions; looking upstream; discharge 102,000 cfs; showing path of downbound tow navigating the reach

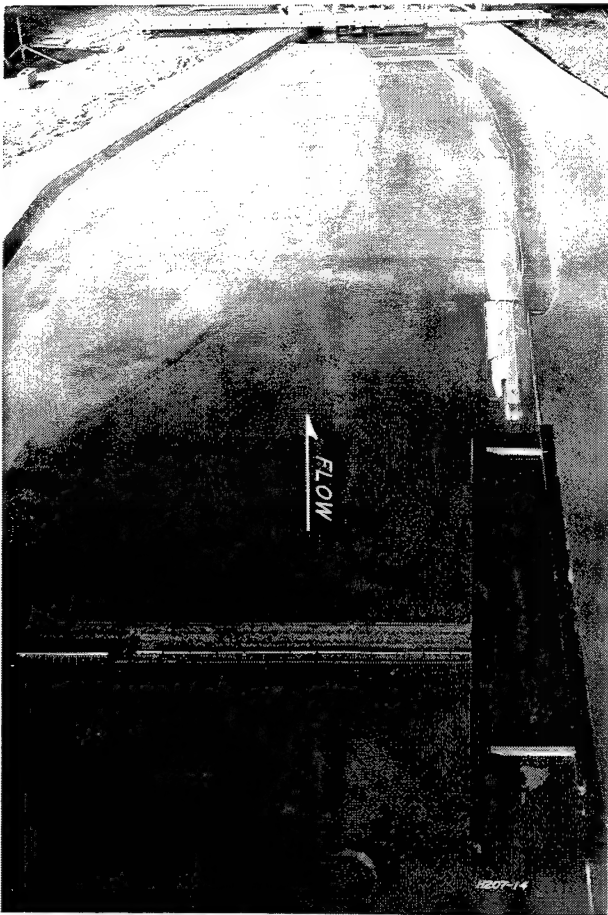


Photo 5. Base Experiment, existing conditions; looking downstream; discharge 15,000 cfs; showing path of downbound tow leaving lock approach

Photo 6. Base Experiment, existing conditions; looking downstream; discharge 15,000 cfs; showing path of upbound tow approaching lock



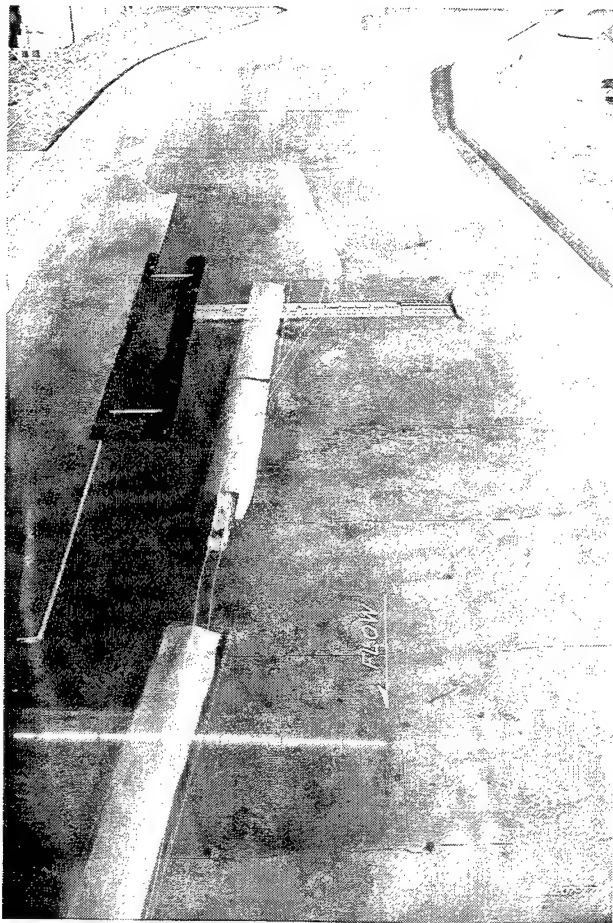


Photo 7. Base Experiment, existing conditions; looking upstream; discharge 20,000 cfs; showing path of upbound tow navigating the reach. Note change of direction as tow passes through navigation pass

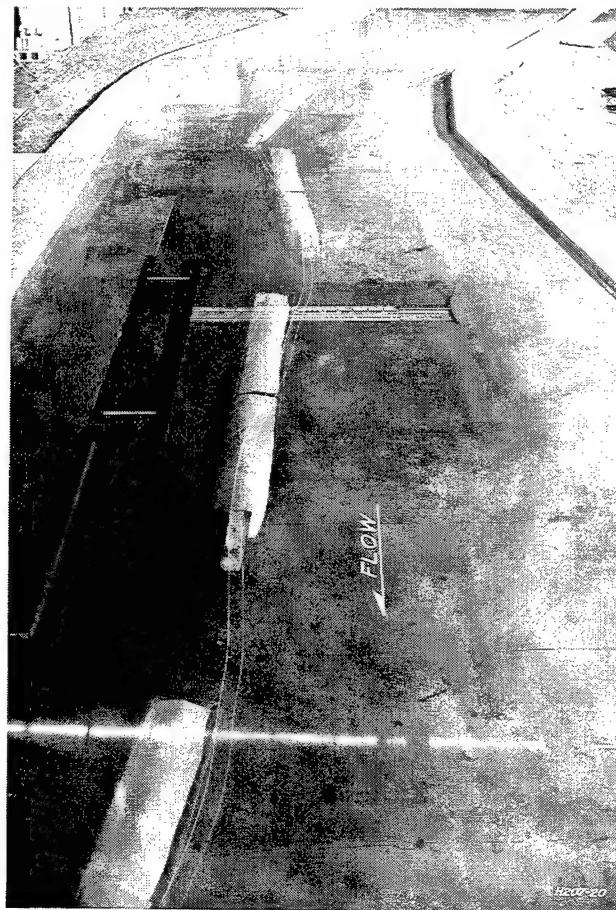


Photo 8. Base Experiment, existing conditions; looking upstream; discharge 44,000 cfs; showing path of upbound tow navigating the reach. Note change of direction as tow passes through navigation pass

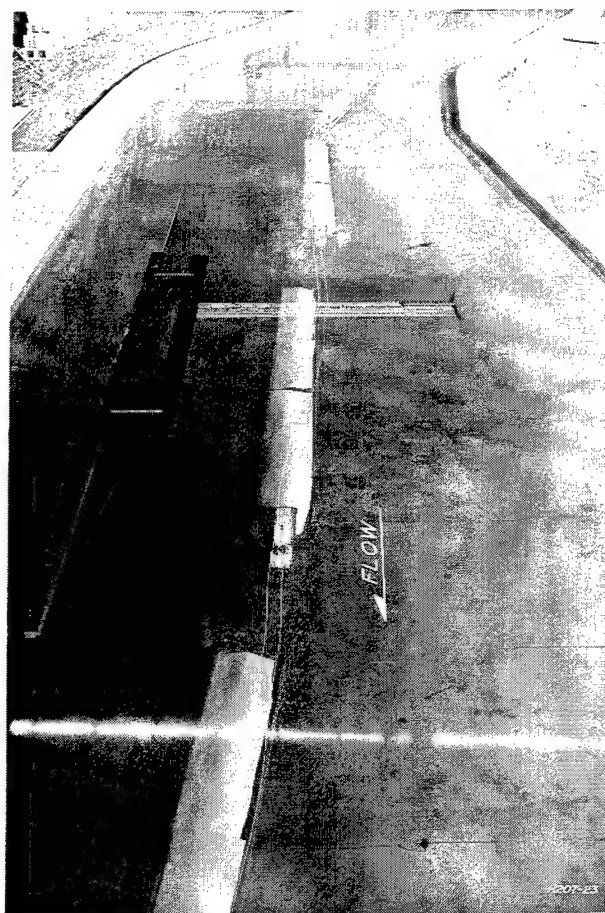
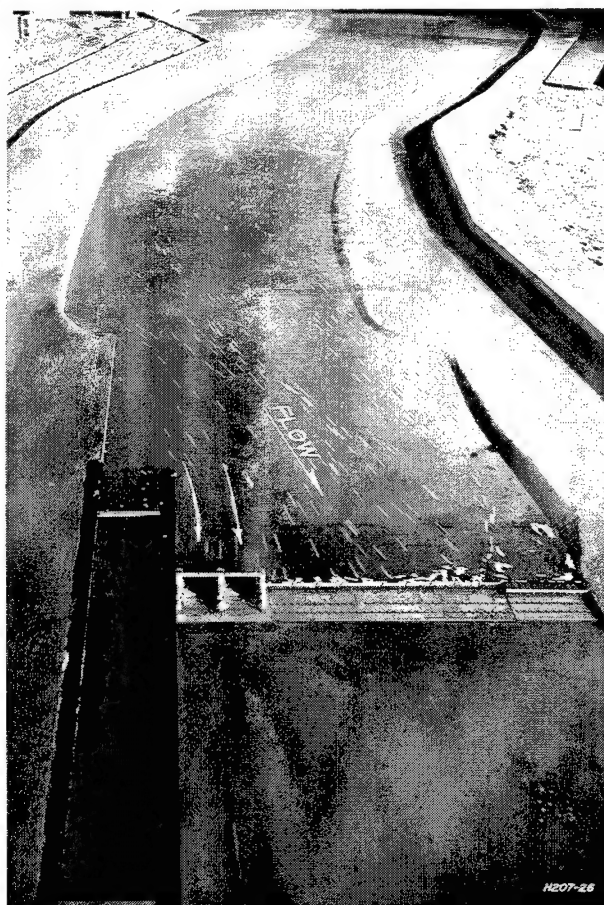


Photo 9. Base Experiment, existing conditions; looking upstream; discharge 102,000 cfs; showing path of upbound tow navigating the reach

Photo 10. Plan A, looking upstream; discharge 15,000 cfs; confetti showing surface current patterns in upper lock approach



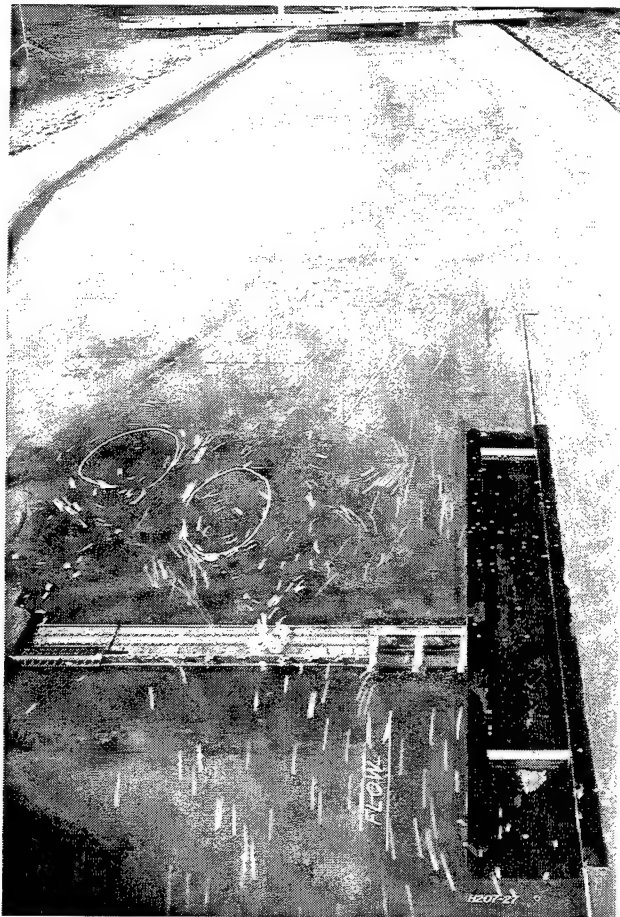


Photo 11. Plan A, looking downstream;
discharge 15,000 cfs; confetti showing
surface current patterns in lower lock
approach

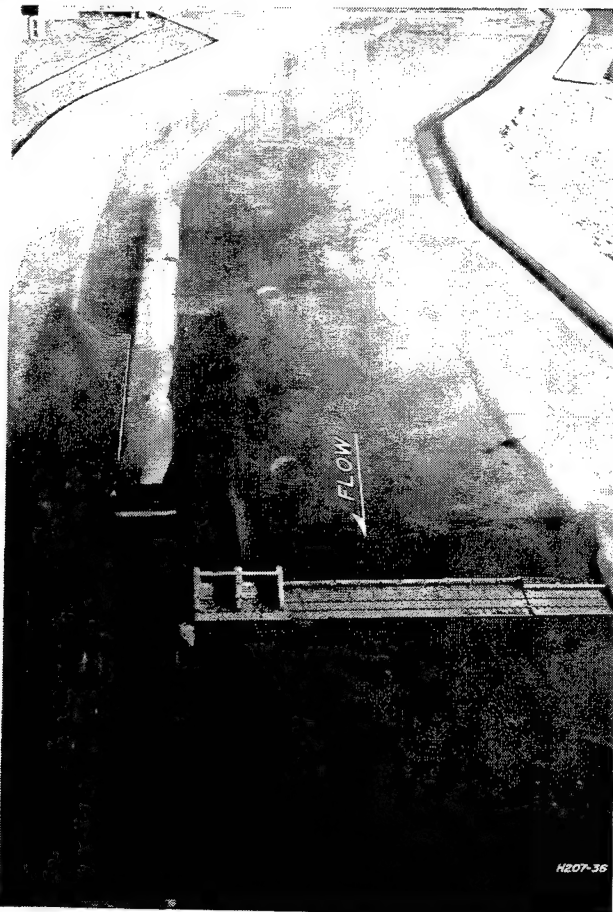


Photo 12. Plan A, looking upstream;
discharge 15,000 cfs; showing path of
downbound tow approaching lock

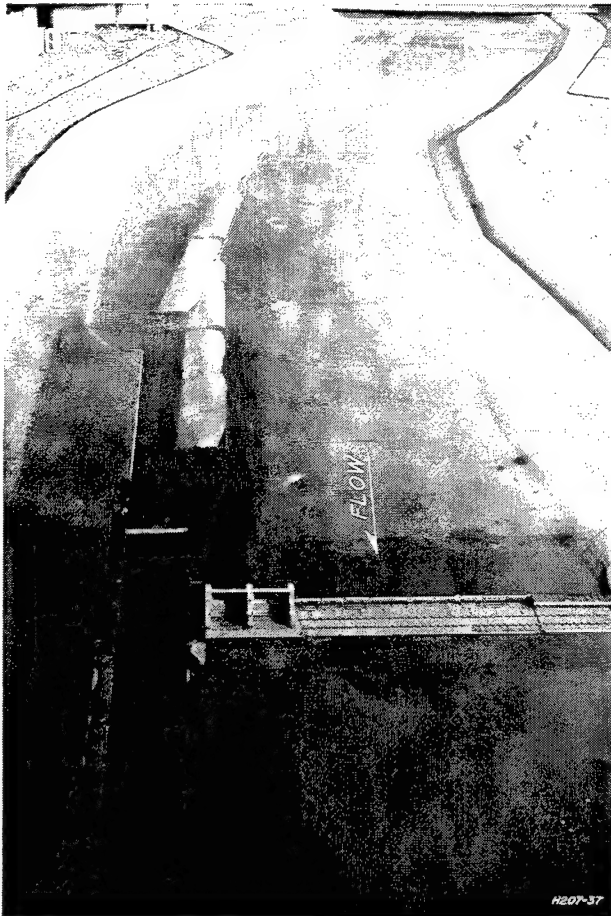
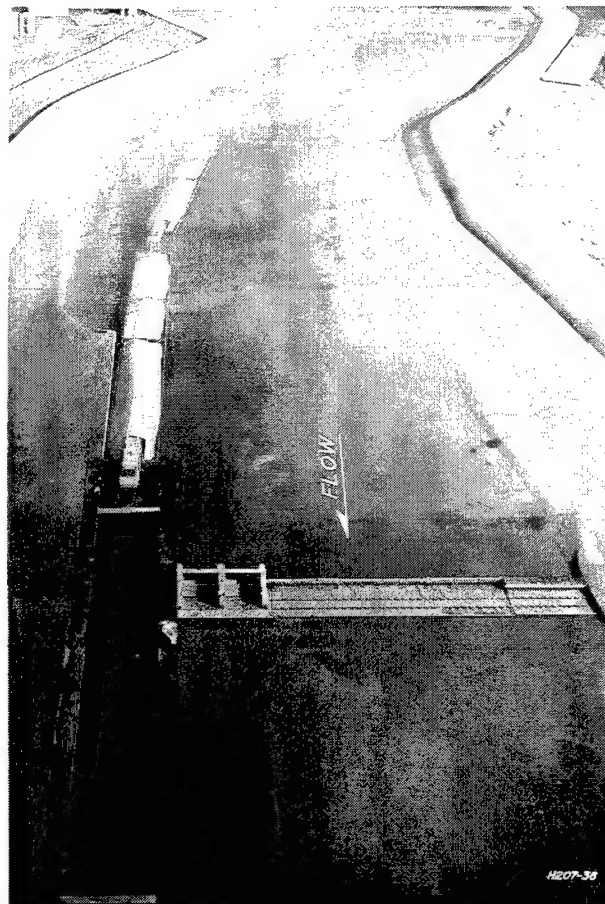


Photo 13. Plan A, looking upstream;
discharge 15,000 cfs; showing path of
downbound tow approaching lock. Note
outdraft near upper guide wall

Photo 14. Plan A, looking upstream;
discharge 15,000 cfs; showing path of
upbound tow leaving lock approach



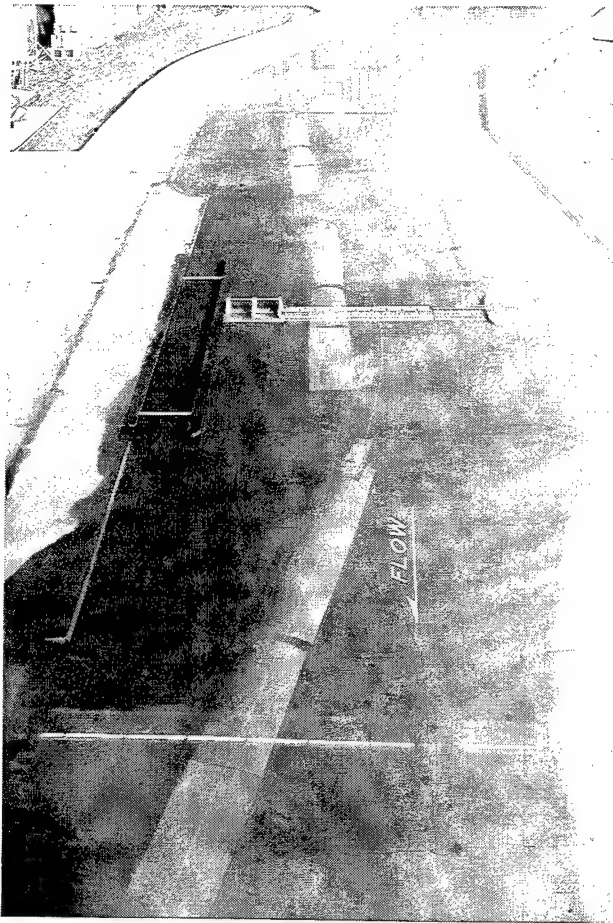


Photo 15. Plan A, looking upstream;
discharge 20,000 cfs; showing path of
downbound tow navigating the reach.
Note clearance between tow and
proposed tainter gates

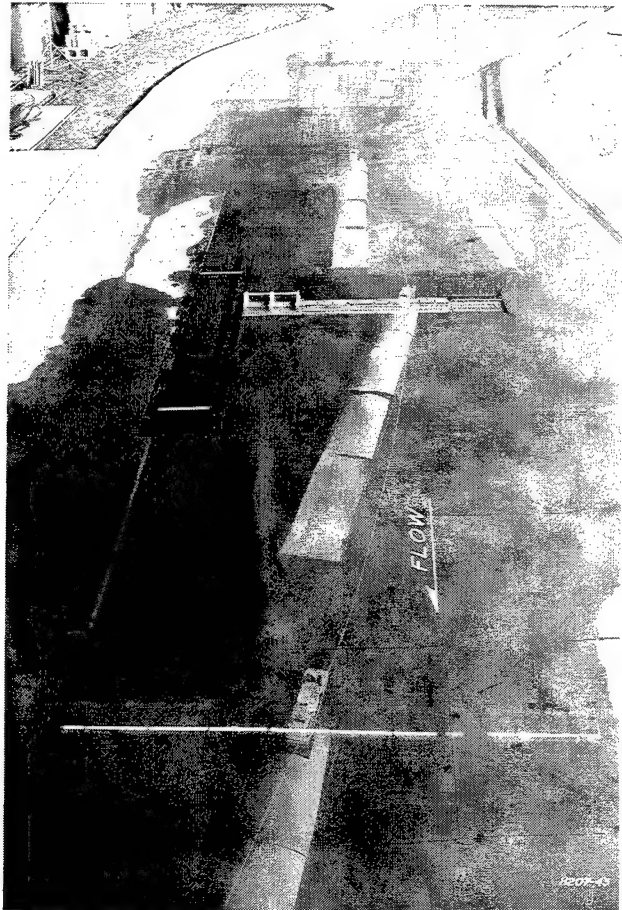


Photo 16. Plan A, looking upstream;
discharge 44,000 cfs; showing path of
downbound tow navigating the reach.
Note change of alignment and width of
pass occupied as tow moves through
navigation pass

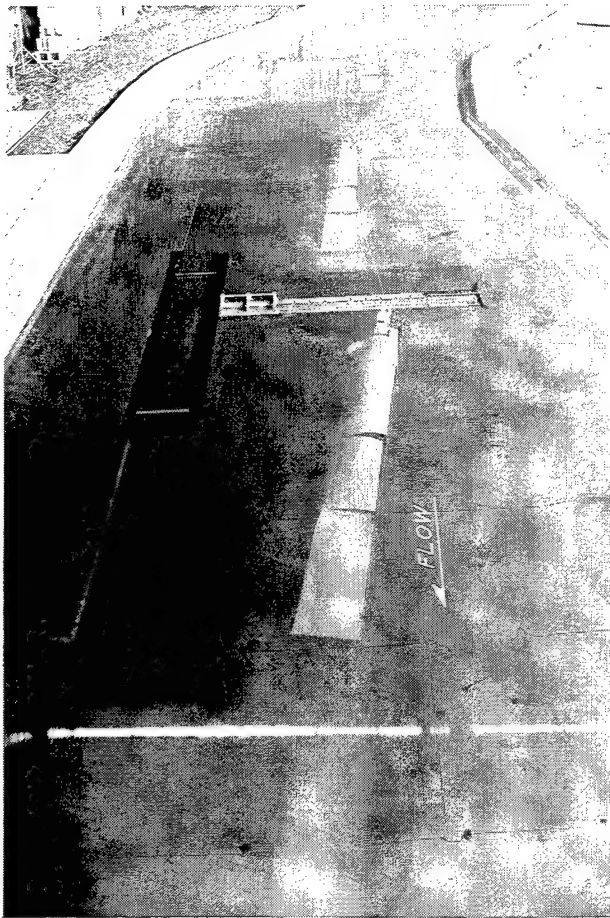


Photo 17. Plan A, looking upstream;
discharge 102,000 cfs; showing path of
downbound tow navigating the reach
along the left descending bank

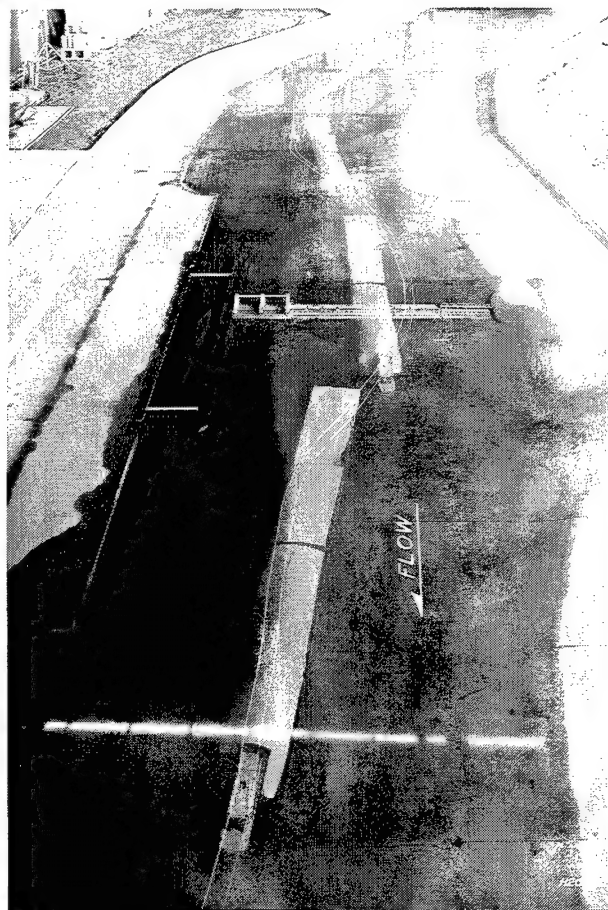


Photo 18. Plan A, looking upstream;
discharge 20,000 cfs; showing path of
upbound tow navigating the reach.
Note change of alignment as tow moves
through navigation pass

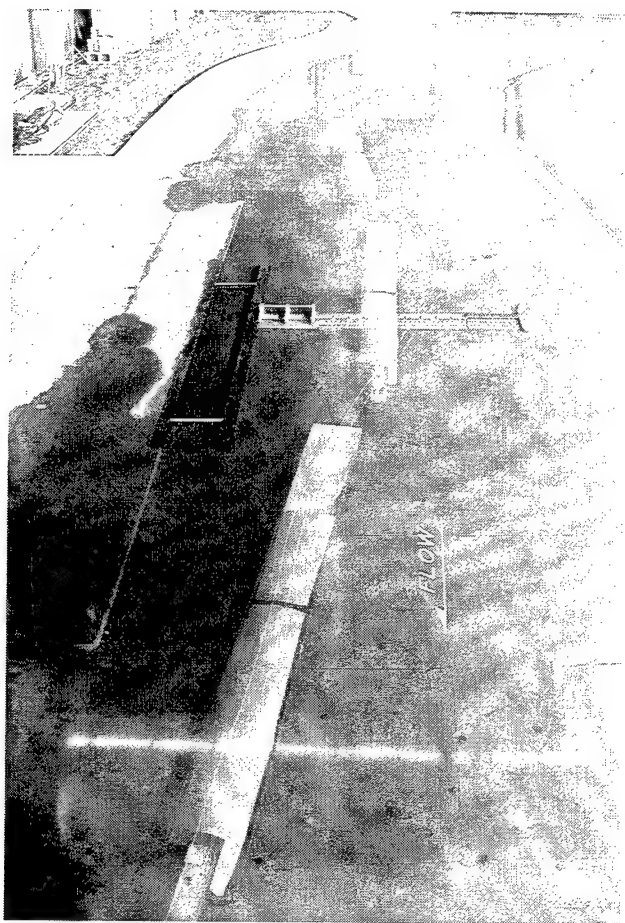
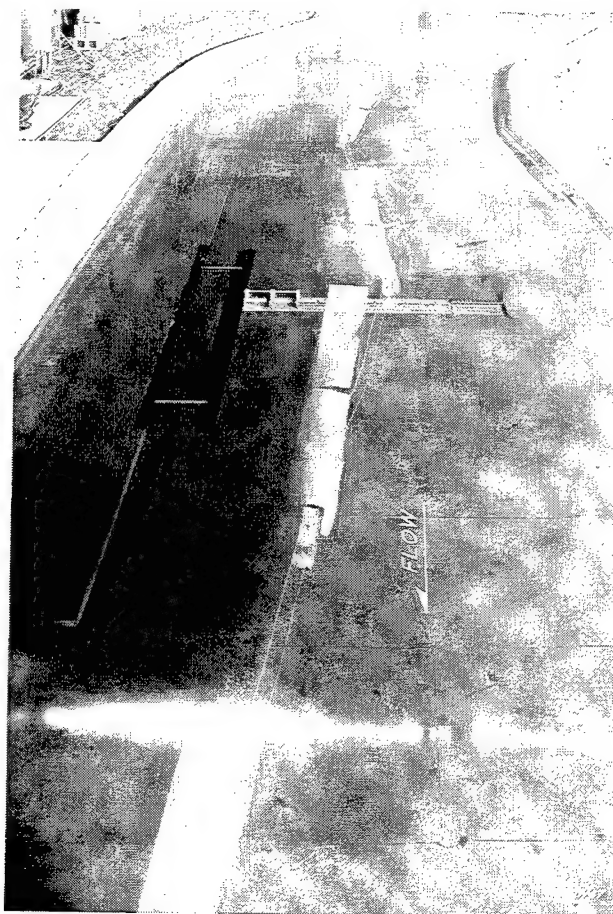


Photo 19. Plan A, looking upstream;
discharge 44,000 cfs; showing path of
upbound tow navigating the reach. Note
change of alignment as tow moves
through navigation pass and path of
stern as indicated by light streak.

Photo 20. Plan A, looking upstream;
discharge 102,000 cfs; showing path of
upbound tow navigating the reach.
Note change of alignment as tow moves
through navigation pass and path of
stern as indicated by light streak



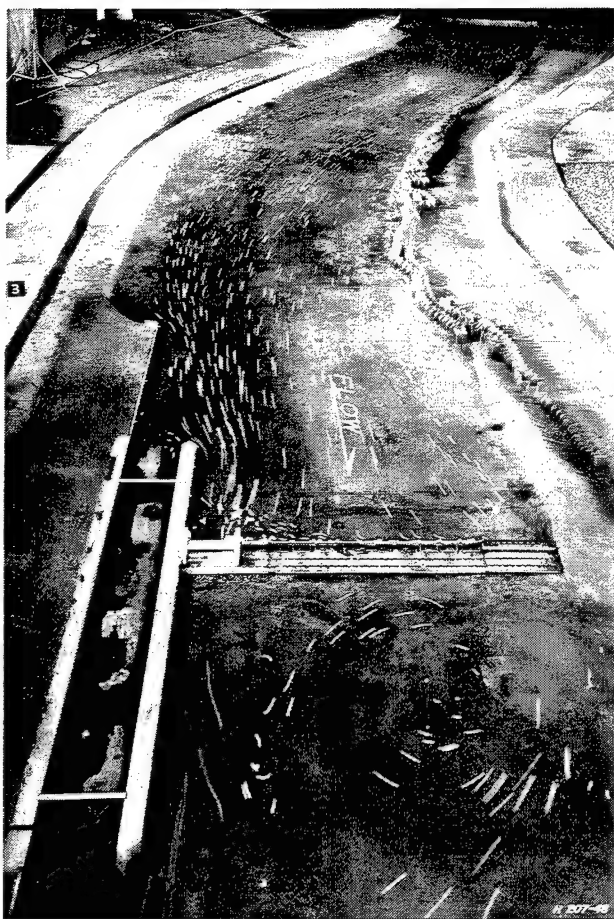


Photo 21. Plan B, looking upstream;
discharge 15,000 cfs; confetti showing
surface current patterns in upper lock
approach



Photo 22. Plan B, looking downstream;
discharge 15,000 cfs; confetti showing
surface current patterns in lower lock
approach

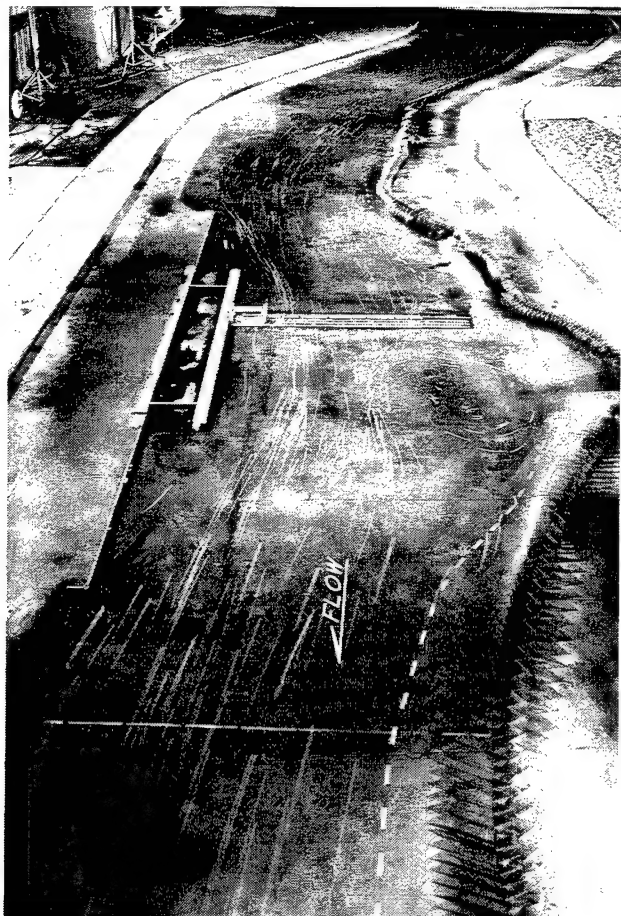


Photo 23. Plan B, looking upstream;
discharge 20,000 cfs; lock closed;
confetti showing surface current patterns
through navigation pass

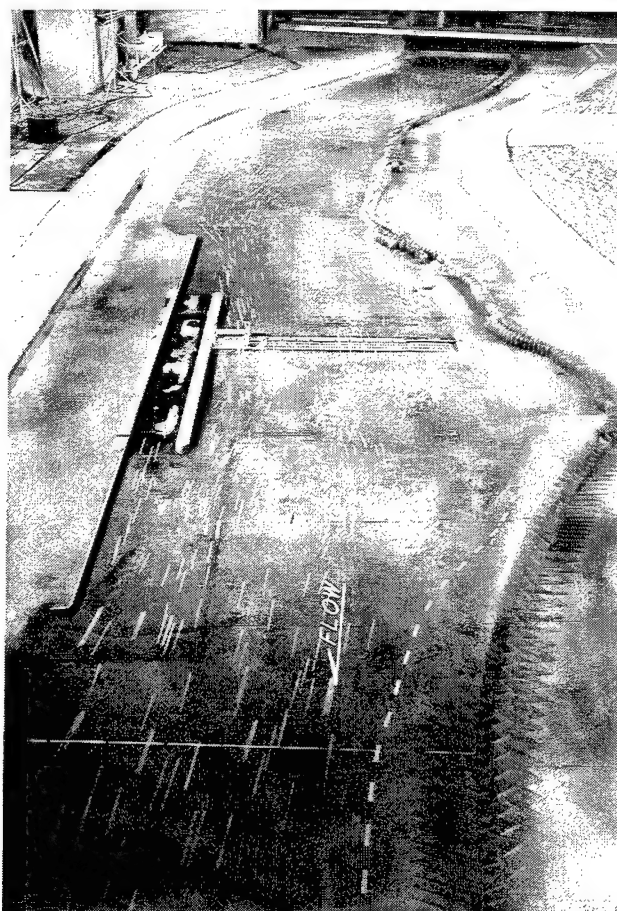


Photo 24. Plan B, looking upstream;
discharge 20,000 cfs; lock open as
floodway; confetti showing surface
current patterns through navigation
pass

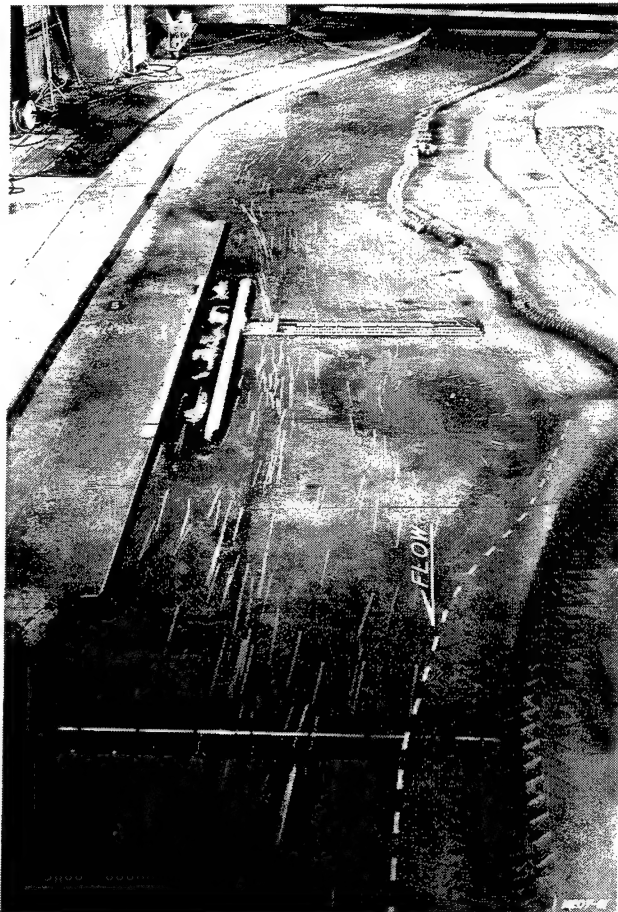


Photo 25. Plan B, looking upstream;
discharge 44,000 cfs; lock open as
floodway; confetti showing surface
current patterns through navigation pass

Photo 26. Plan B, looking upstream;
discharge 102,000 cfs; lock open as
floodway; confetti showing surface
current patterns through navigation
pass



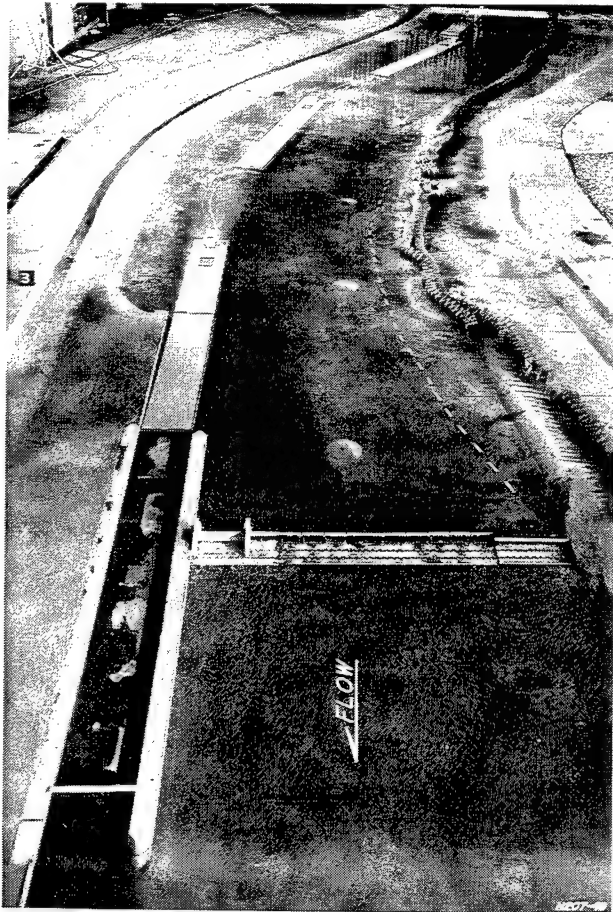


Photo 27. Plan B, looking upstream;
discharge 15,000 cfs; showing path of
downbound tow approaching lock

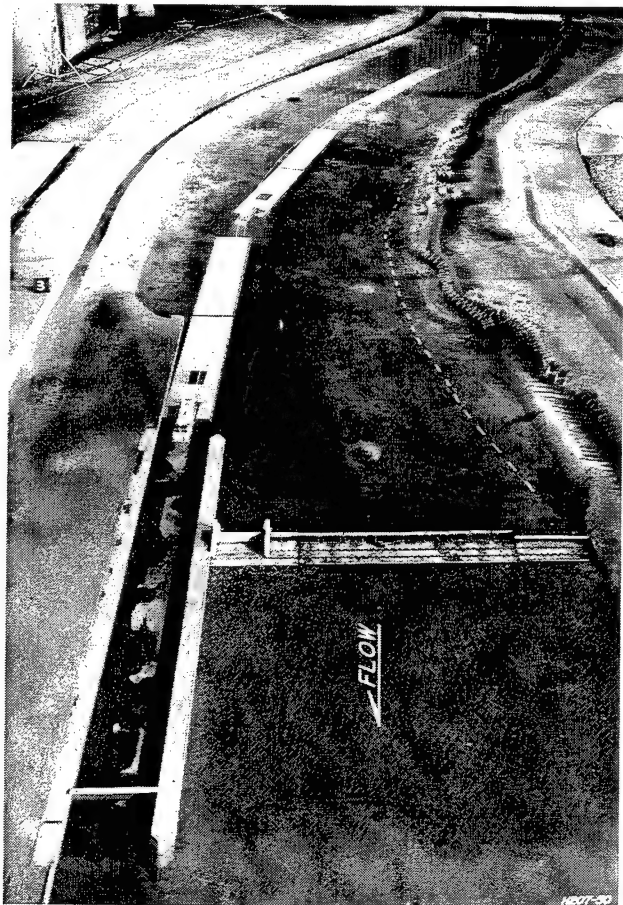


Photo 28. Plan B, looking upstream;
discharge 15,000 cfs; showing path
of upbound tow leaving lock approach

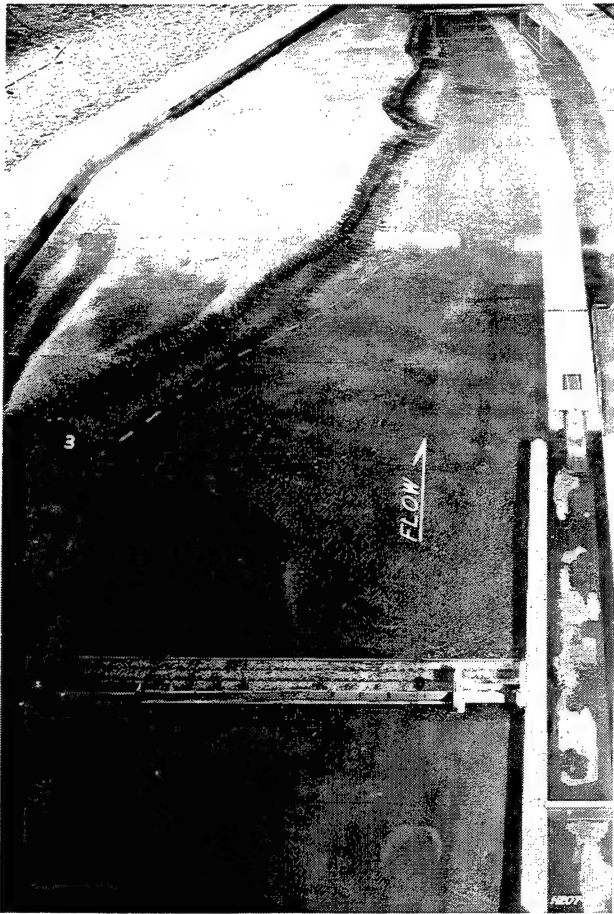


Photo 29. Plan B, looking downstream; discharge 15,000 cfs; showing path of downbound tow leaving lock approach

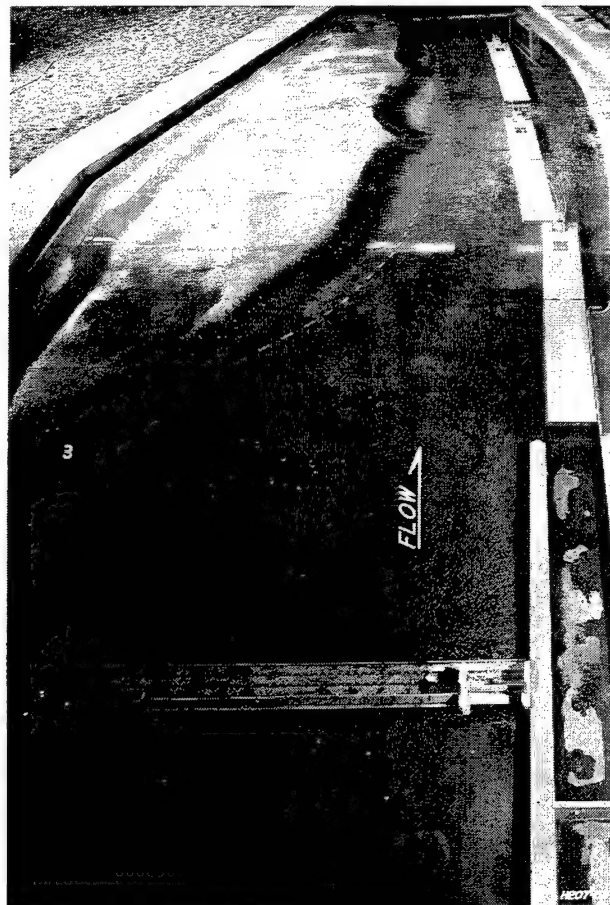


Photo 30. Plan B, looking downstream; discharge 15,000 cfs; showing path of upbound tow approaching lock

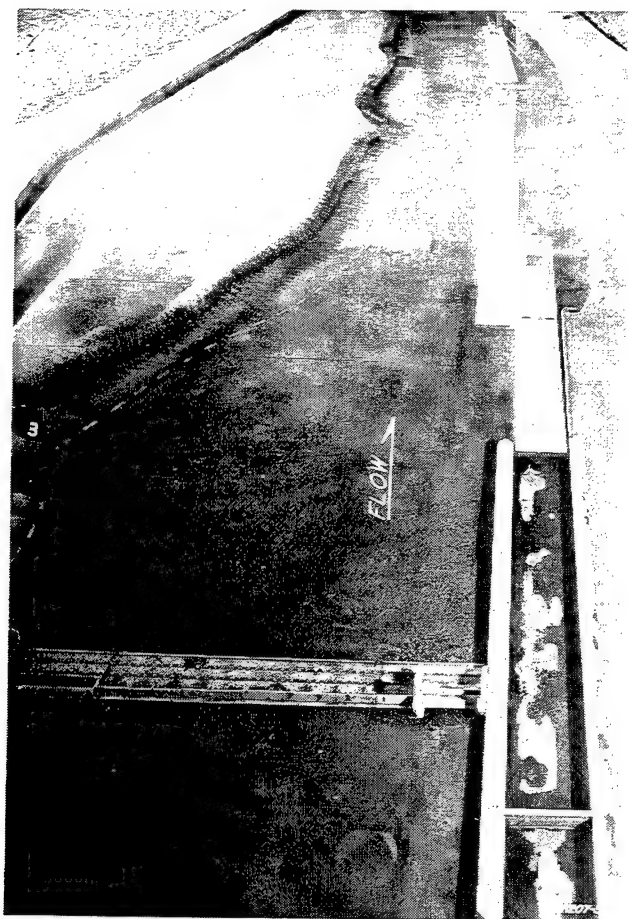
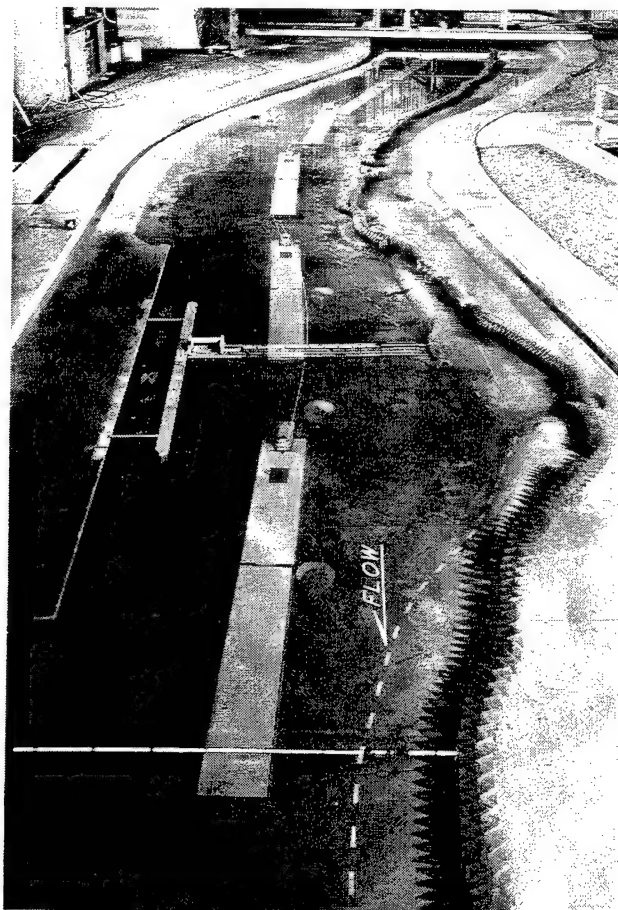


Photo 31. Plan B, looking downstream; discharge 15,000 cfs; showing path of upbound tow approaching lock from midchannel

Photo 32. Plan B, looking upstream; discharge 20,000 cfs; lock closed; showing path of downbound tow navigating the reach. Note clearance between tow and proposed tainter gate



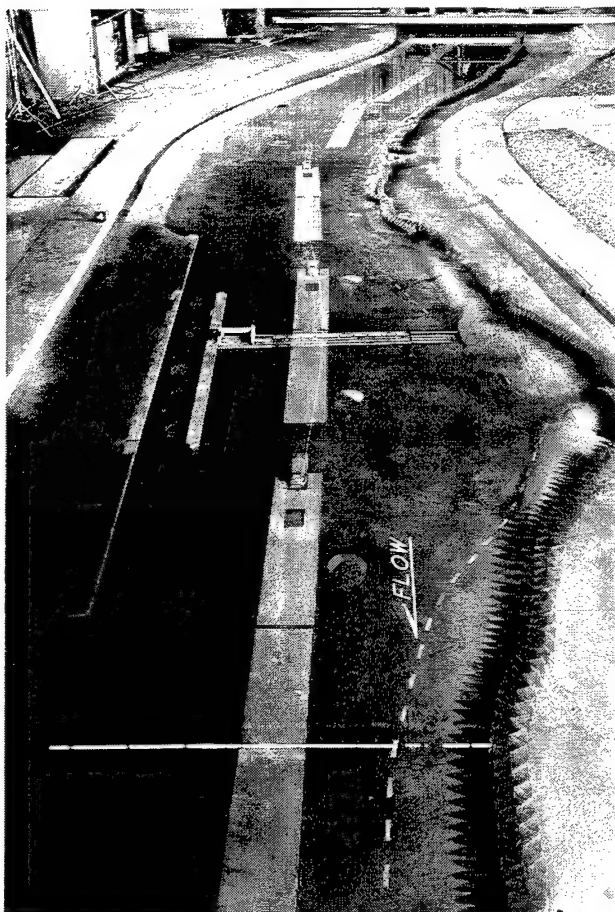
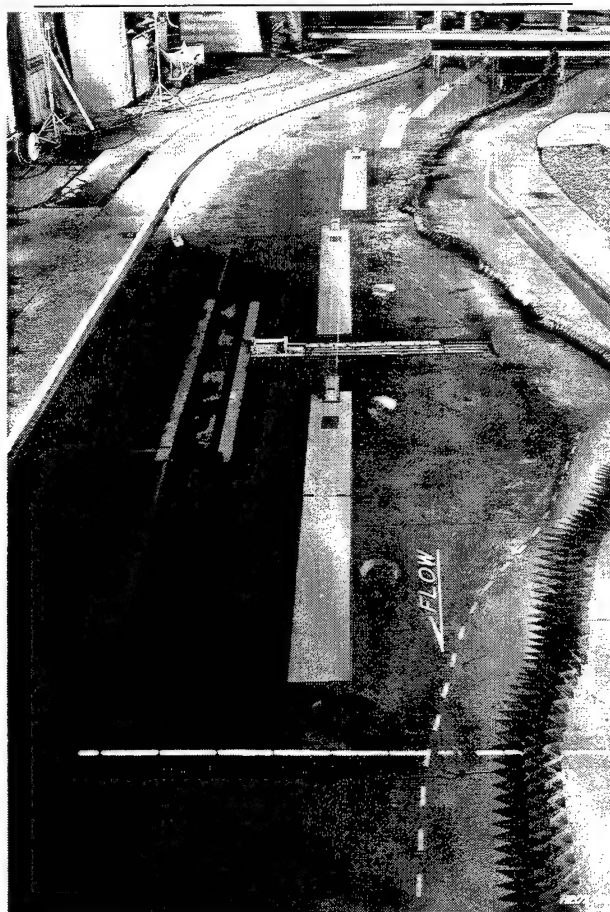


Photo 33. Plan B, looking upstream;
discharge 30,000 cfs; lock open;
showing path of downbound tow
navigating the reach. Note clearance
between tow and proposed tainter gate

Photo 34. Plan B, looking upstream;
discharge 44,000 cfs; lock open;
showing path of downbound tow
navigating the reach



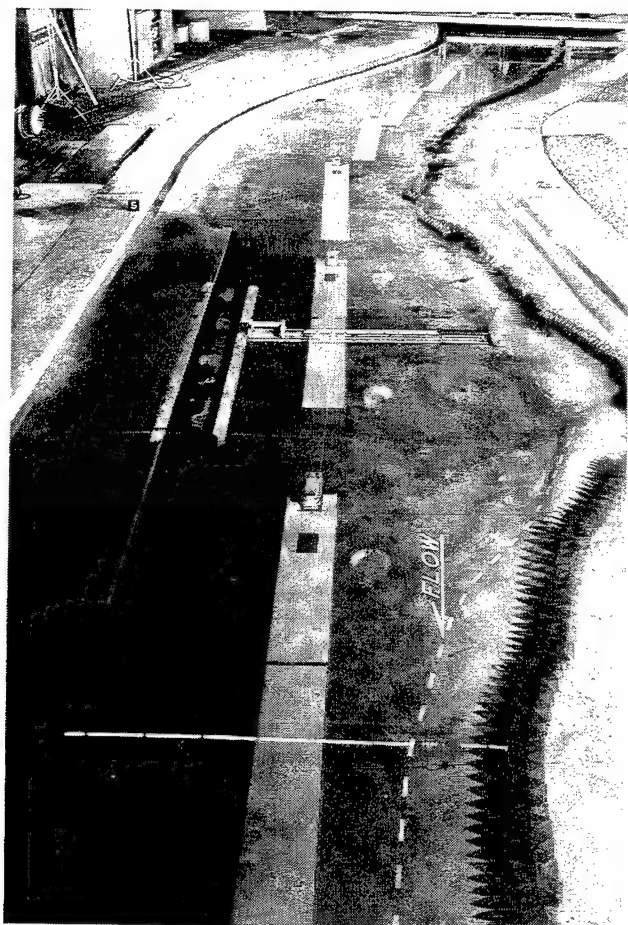


Photo 35. Plan B, looking upstream;
discharge 102,000 cfs; lock open;
showing path of downbound tow
navigating the reach

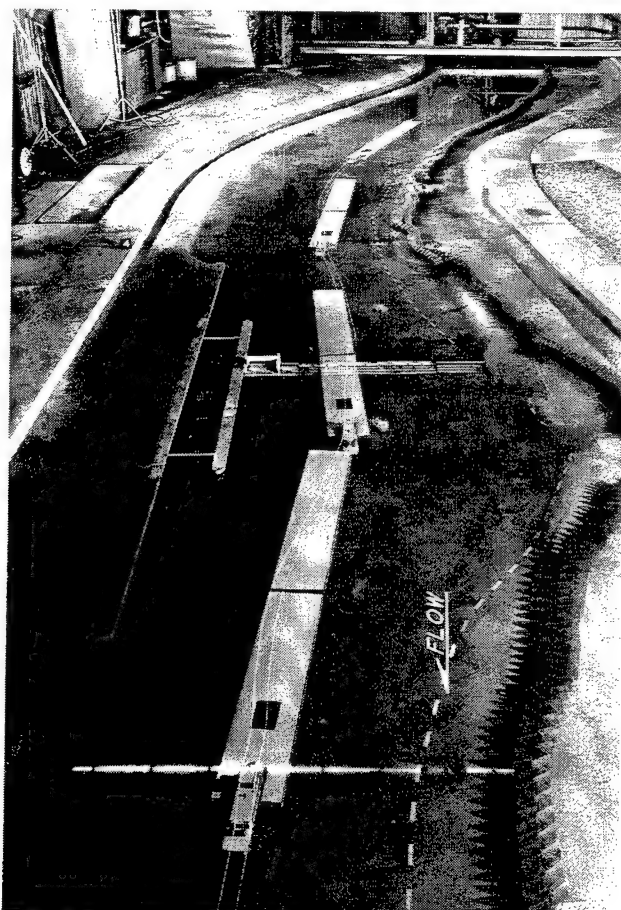


Photo 36. Plan B, looking upstream;
discharge 30,000 cfs; lock closed;
showing path of upbound tow navigating
the reach. Note maneuvering required
through the navigation pass as shown
by the tow lights

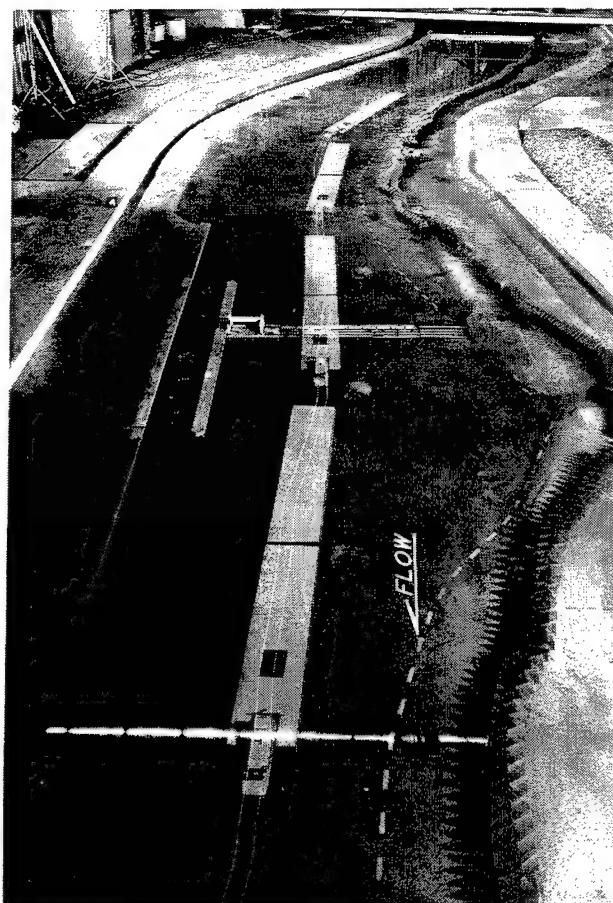
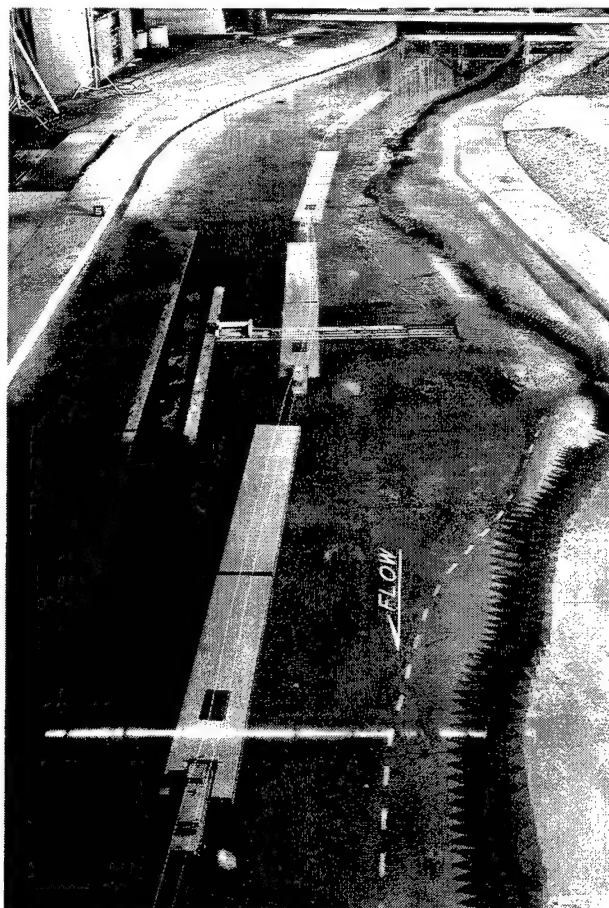


Photo 37. Plan B, looking upstream;
discharge 30,000 cfs; lock open;
showing path of upbound tow navigating
the reach. Note reduced amount of
maneuvering required through the
navigation pass compared with lock
closed

Photo 38. Plan B, looking upstream;
discharge 44,000 cfs; lock open;
showing path of upbound tow
navigating the reach



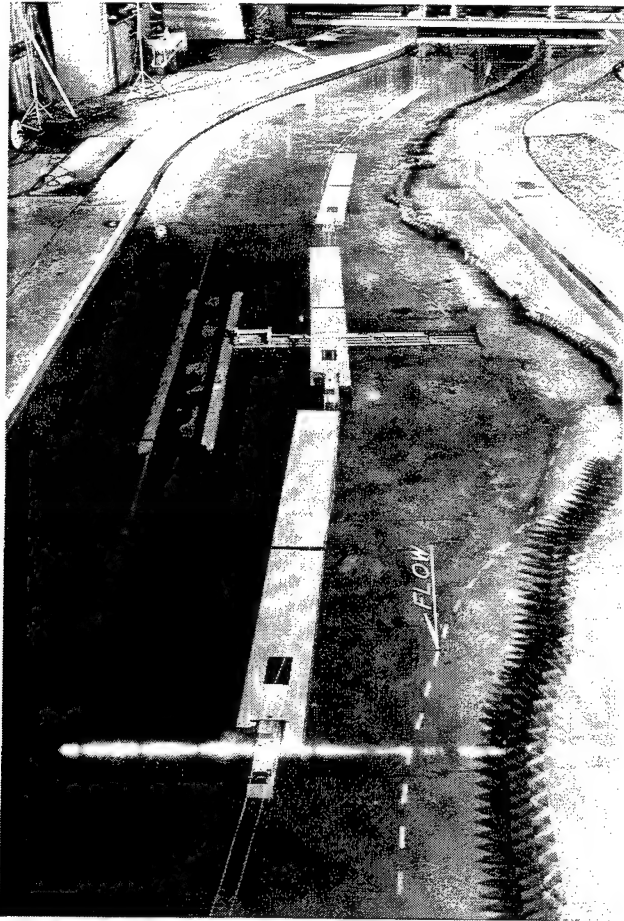


Photo 39. Plan B, looking upstream;
discharge 102,000 cfs; lock open;
showing path of upbound tow navigating
the reach

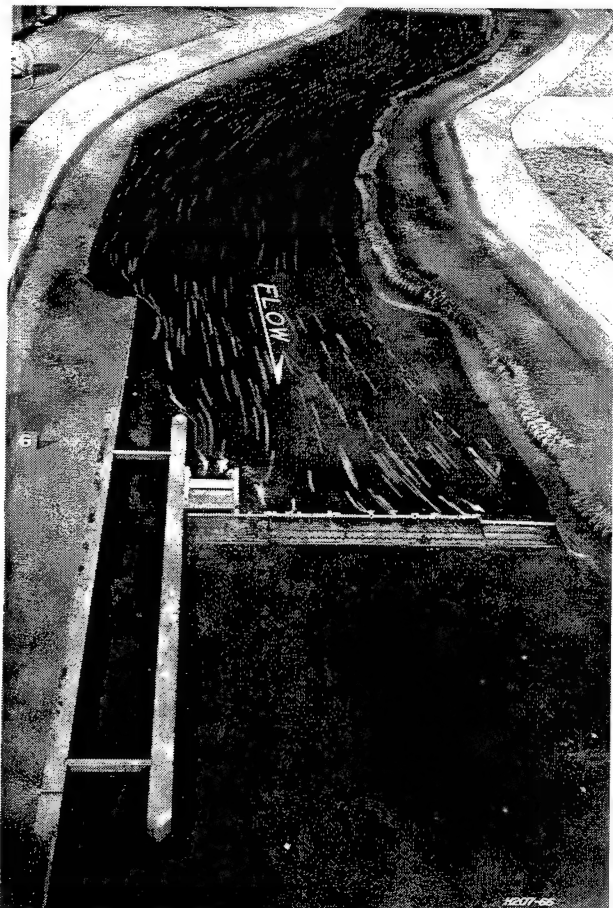


Photo 40. Plan C, looking upstream;
discharge 15,000 cfs; confetti showing
surface current patterns in upper lock
approach

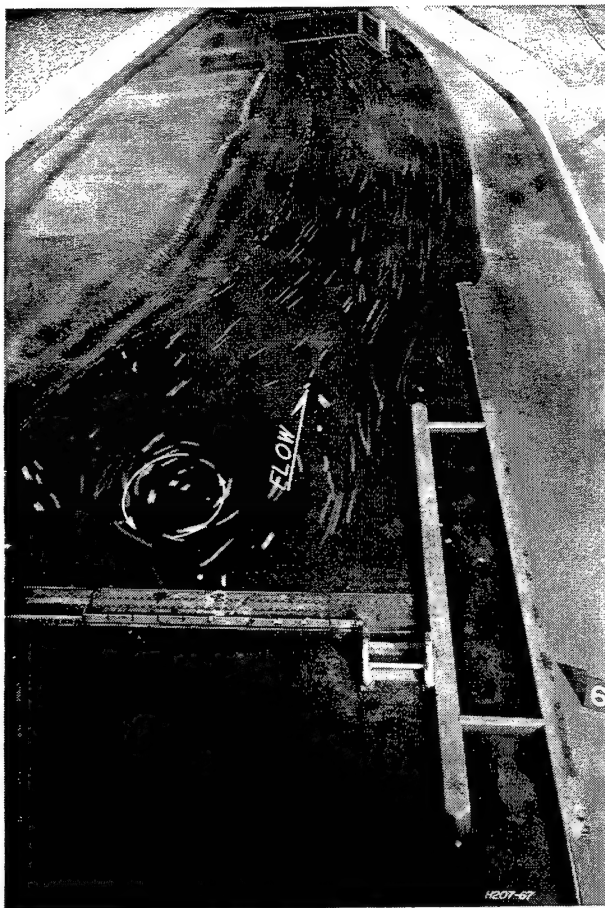
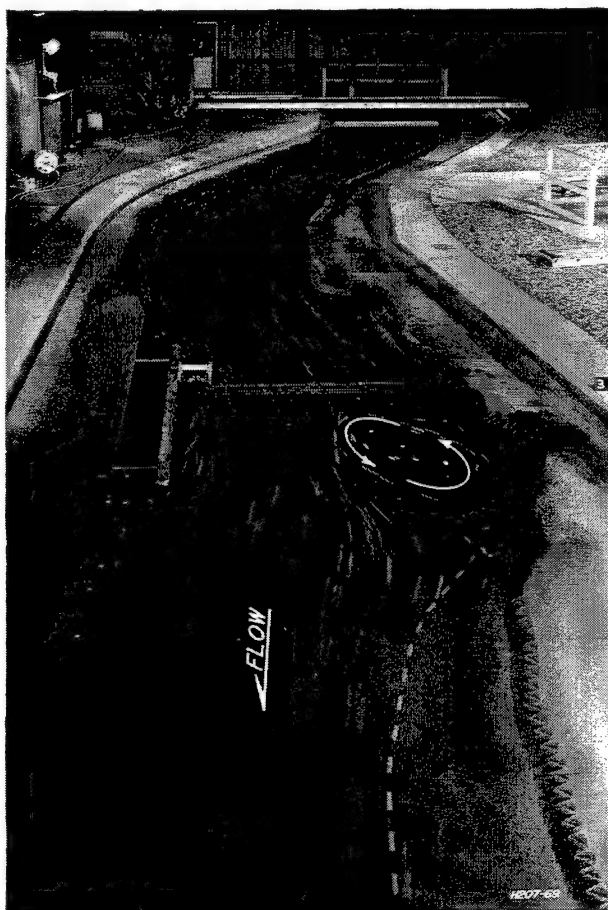


Photo 41. Plan C, looking downstream;
discharge 15,000 cfs; confetti showing
surface current patterns in lower lock
approach

Photo 42. Plan C, looking upstream;
discharge 20,000 cfs; confetti showing
surface current patterns through
navigation pass



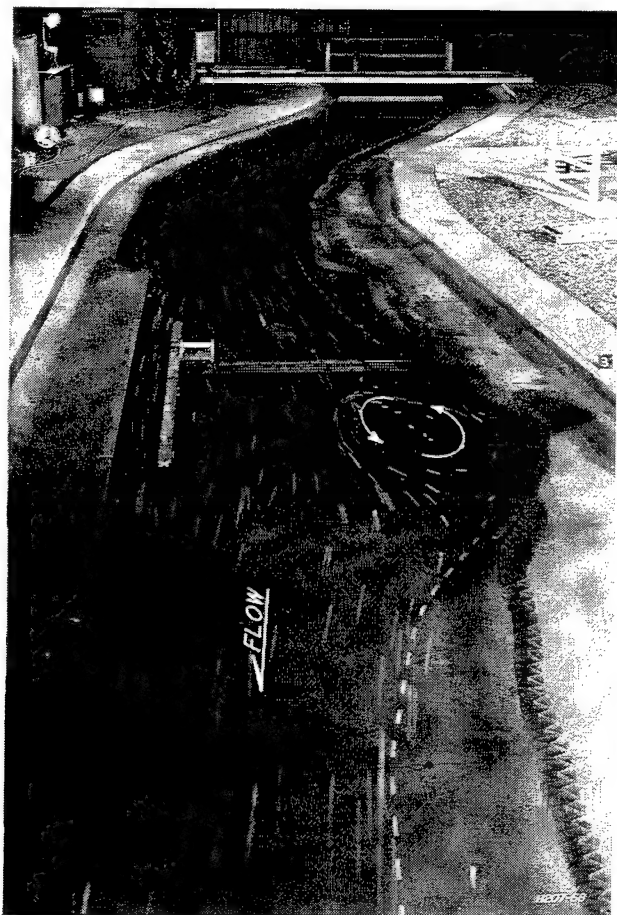
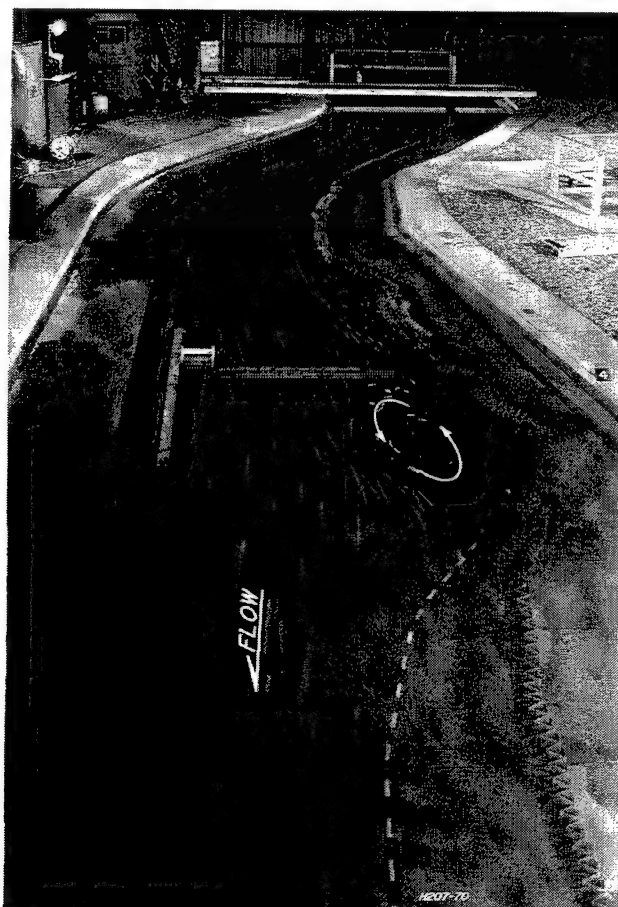


Photo 43. Plan C, looking upstream;
discharge 20,000 cfs; lock open; confetti
showing surface current patterns
through navigation pass

Photo 44. Plan C, looking upstream;
discharge 44,000 cfs; confetti showing
surface current patterns through
navigation pass



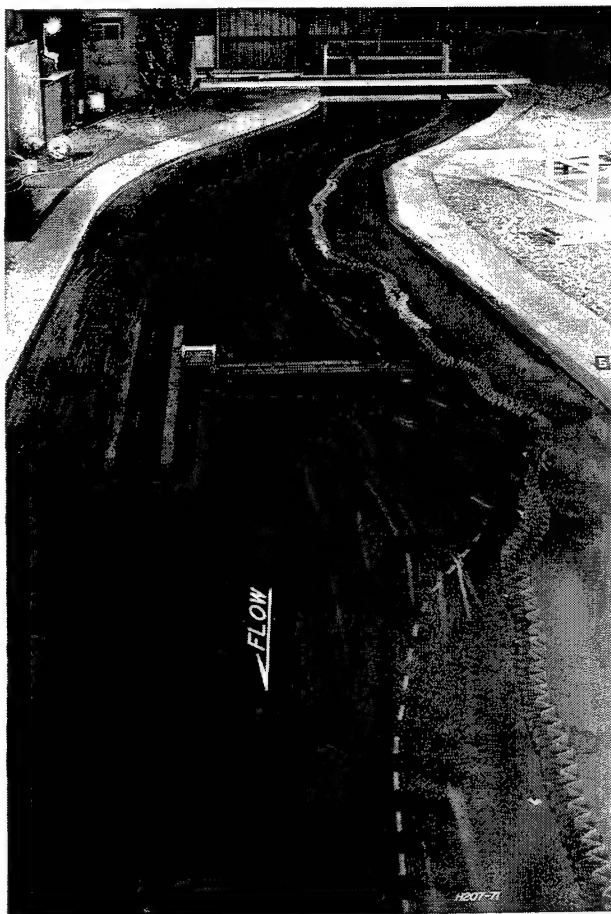


Photo 45. Plan C, looking upstream;
discharge 102,000 cfs; confetti showing
surface current patterns through
navigation pass

Photo 46. Plan C, looking upstream;
discharge 15,000 cfs; showing path of
downbound tow approaching the lock



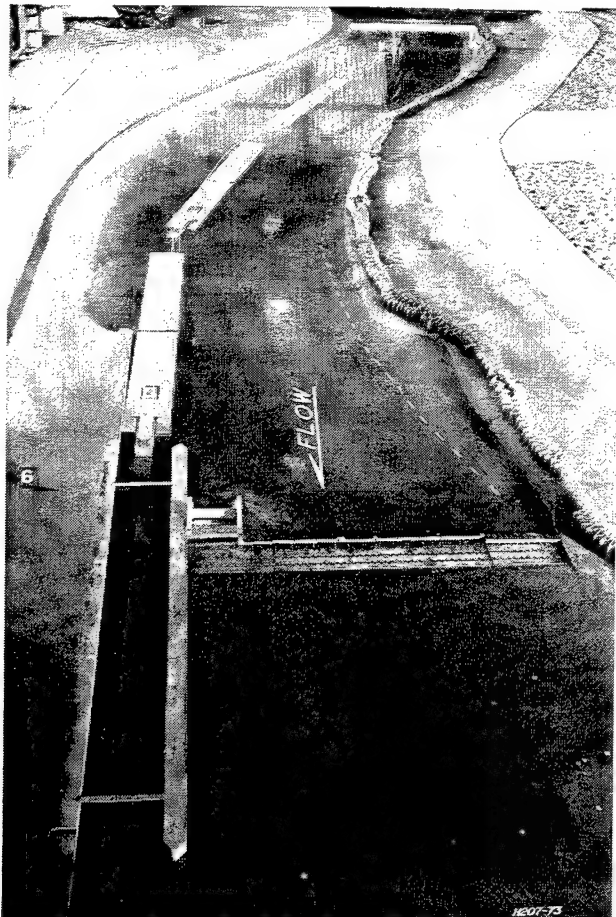
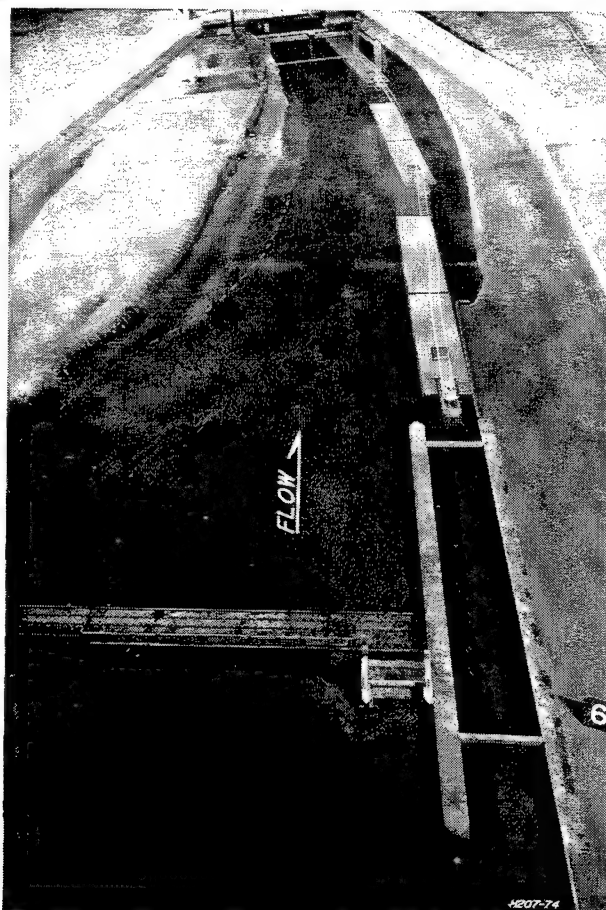


Photo 47. Plan C, looking upstream;
discharge 15,000 cfs; showing path of
upbound tow leaving lock

Photo 48. Plan C, looking downstream;
discharge 15,000 cfs; showing path of
downbound tow leaving lock



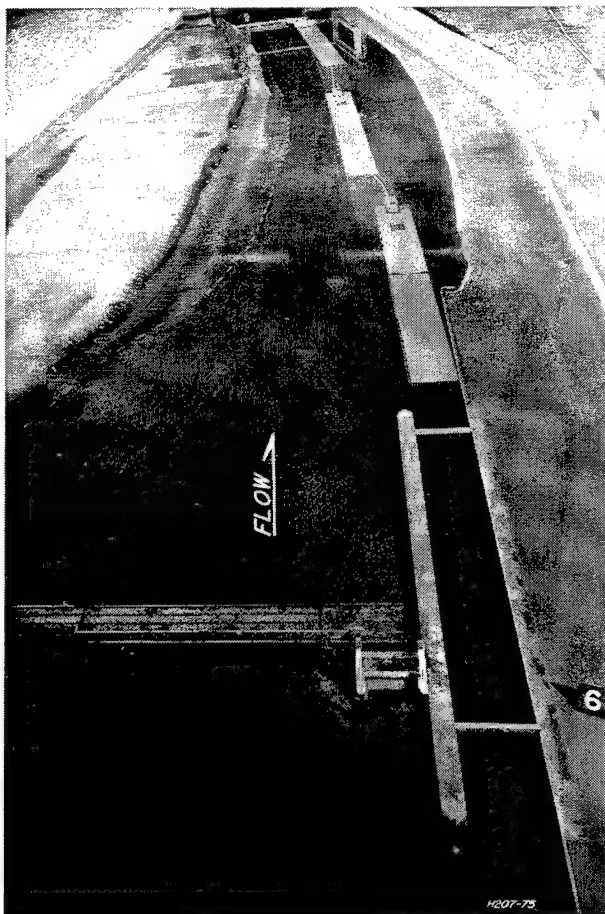


Photo 49. Plan C, looking downstream;
discharge 15,000 cfs; showing path of
upbound tow approaching the lock

Photo 50. Plan C, looking upstream;
discharge 20,000 cfs; showing path of
downbound tow navigating the reach.
Note increase in maneuvering required
as compared to lock open as floodway



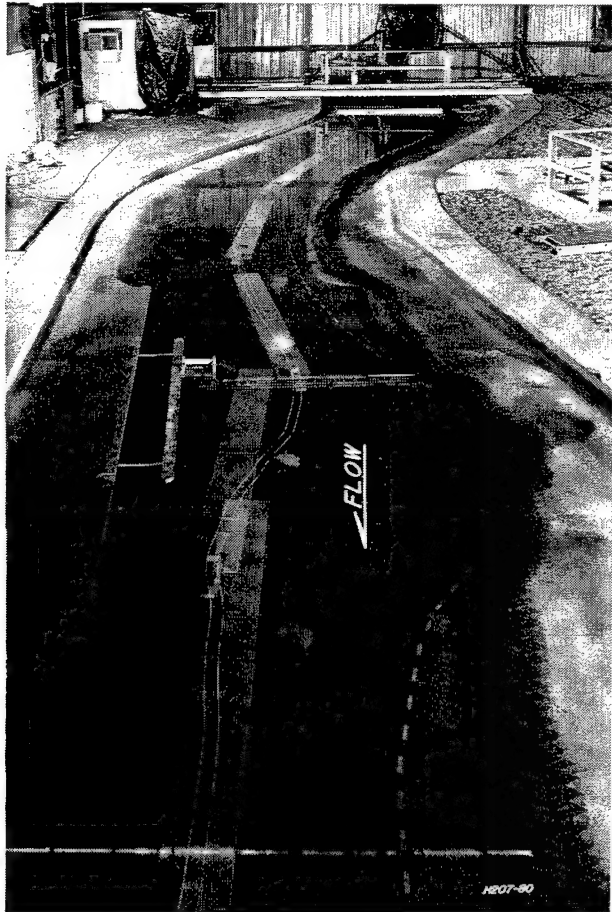


Photo 51. Plan C, looking upstream; discharge 20,000 cfs; showing path of upbound tow navigating the reach. Note increase in maneuvering required compared with lock open

Photo 52. Plan C, looking upstream; discharge 20,000 cfs; lock open as floodway; showing path of downbound tow navigating the reach. Note tow navigating bend upstream of the dam along left channel limits to drive through the navigation pass

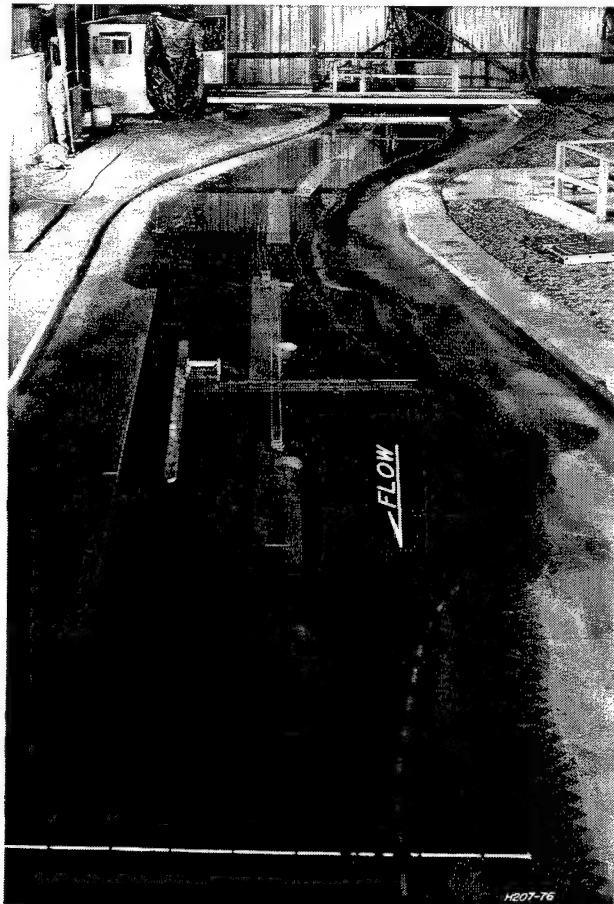




Photo 53. Plan C, looking upstream;
discharge 20,000 cfs; lock open as
floodway; showing path of downbound
tow navigating the reach. Note tow
navigating bend upstream of the dam
about 100 ft riverward of left channel
limits and its position two tow lengths
upstream of the dam

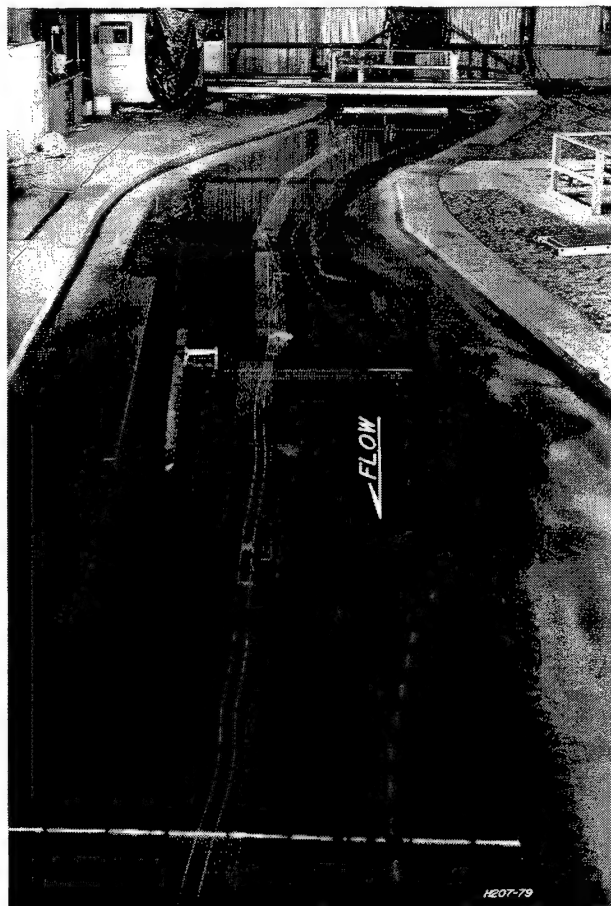


Photo 54. Plan C, looking upstream;
discharge 20,000 cfs; lock open as
floodway; showing path of upbound
tow navigating the reach

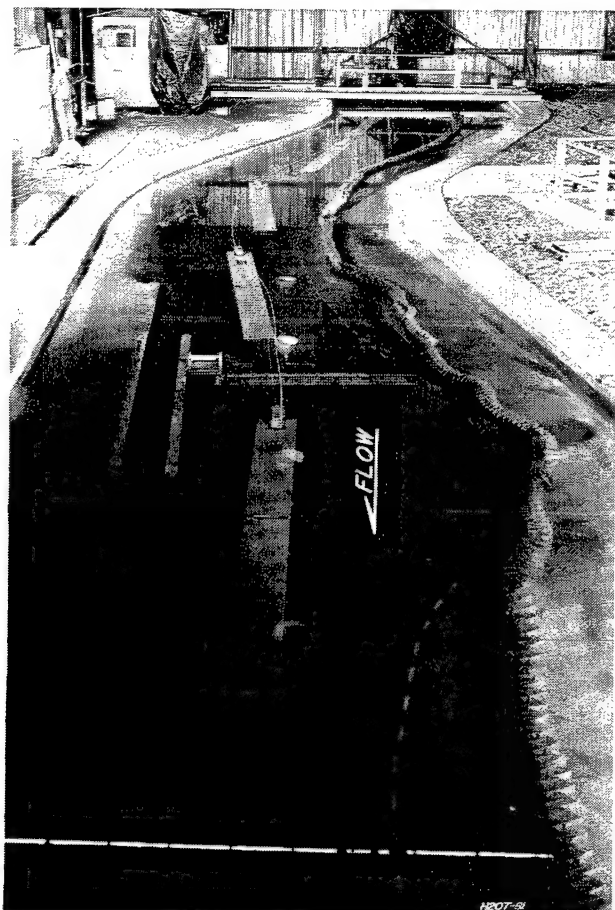
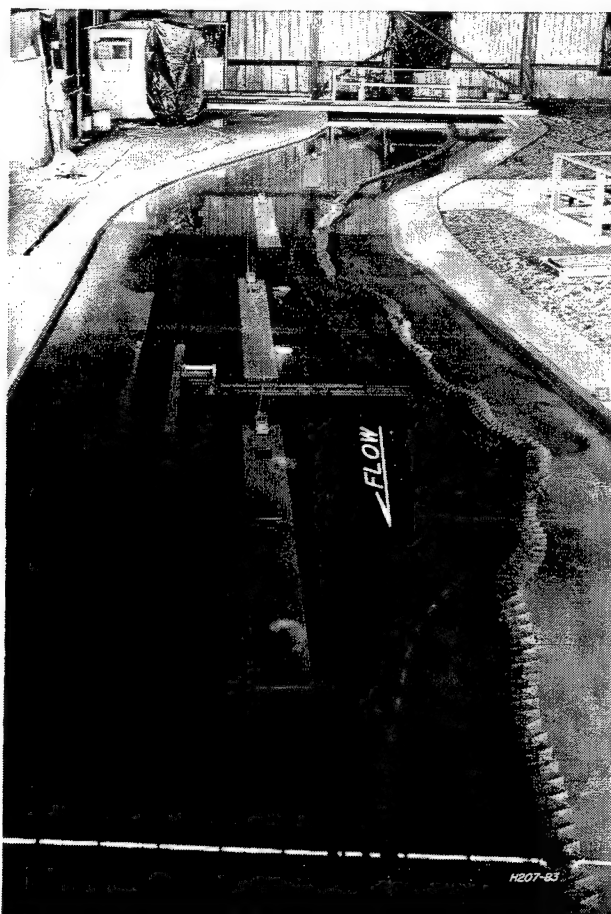


Photo 55. Plan C, looking upstream;
discharge 44,000 cfs; showing path of
downbound tow navigating the reach.
Note position of tow about two tow
lengths upstream of the dam

Photo 56. Plan C, looking upstream;
discharge 102,000 cfs; showing path
of downbound tow navigating the
reach



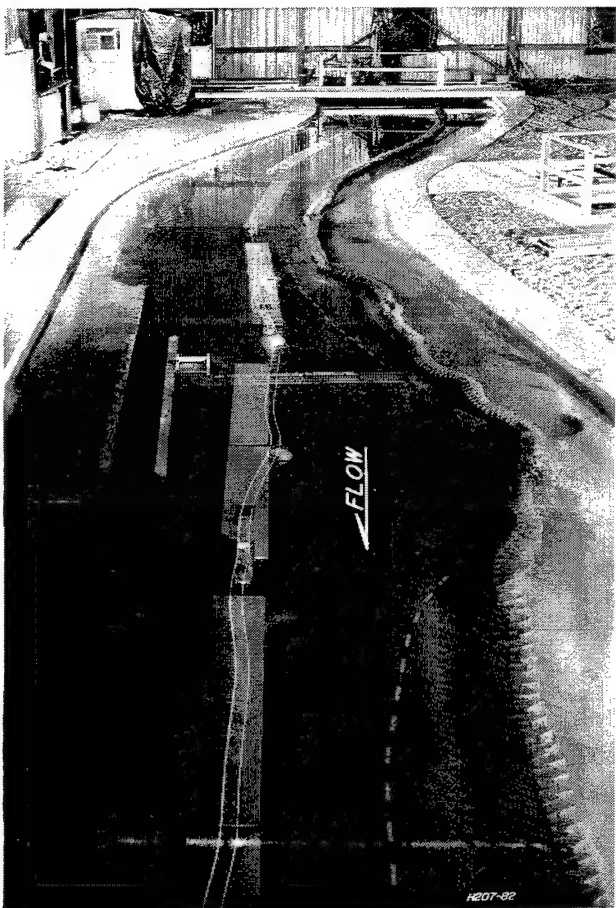
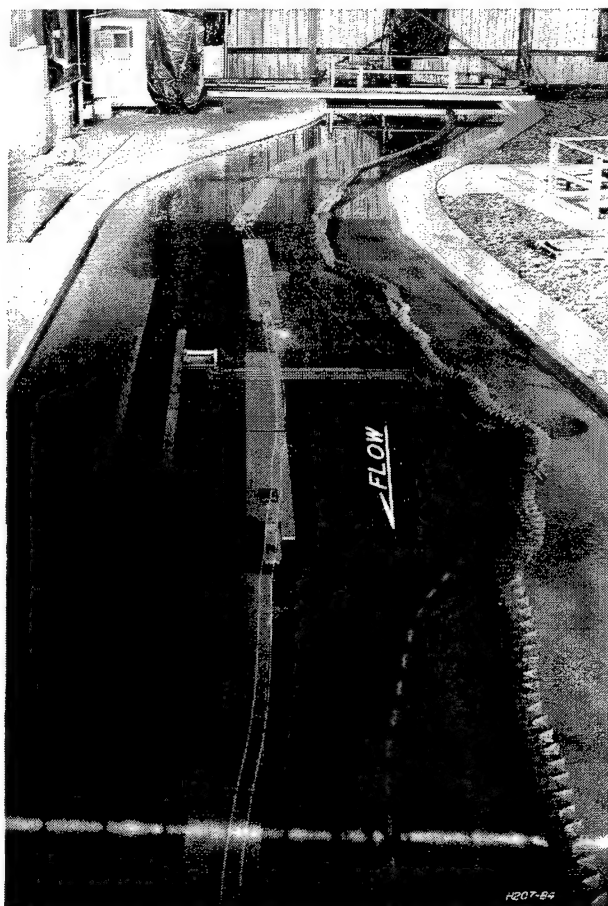


Photo 57. Plan C, looking upstream;
discharge 44,000 cfs; showing path of
upbound tow navigating the reach

Photo 58. Plan C, looking upstream;
discharge 102,000 cfs; showing path
of upbound tow navigating the reach



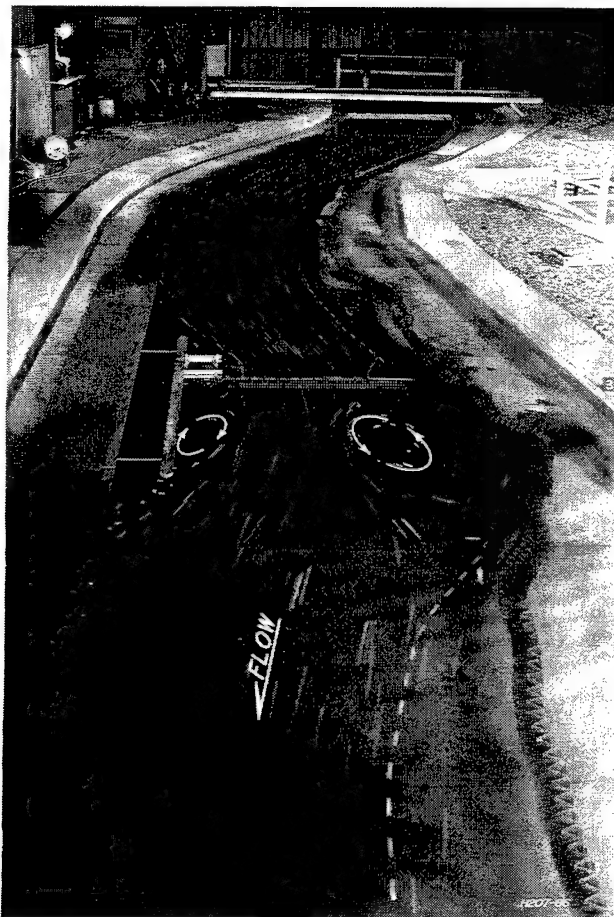


Photo 59. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock closed; confetti showing surface current patterns through navigation pass

Photo 60. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock open as floodway; confetti showing surface current patterns through navigation pass

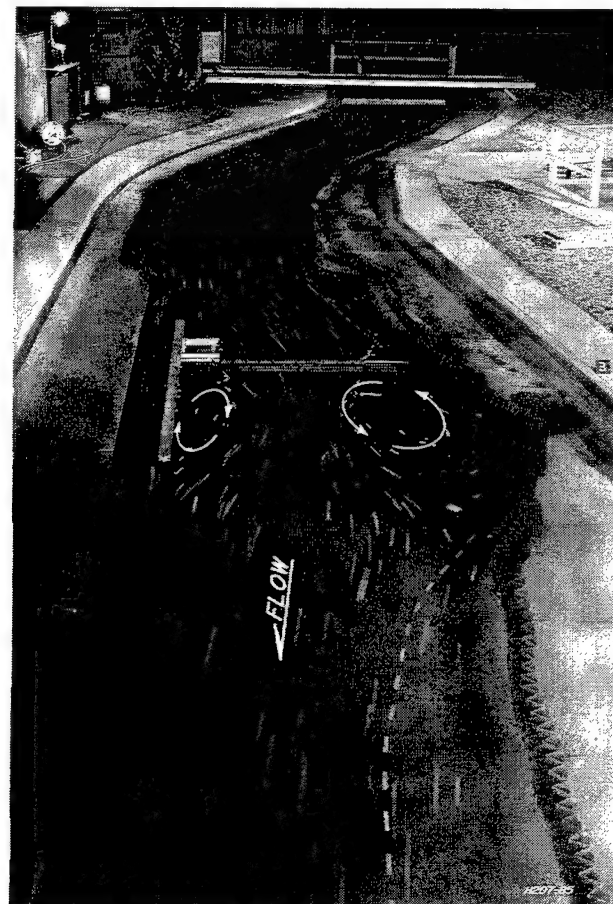
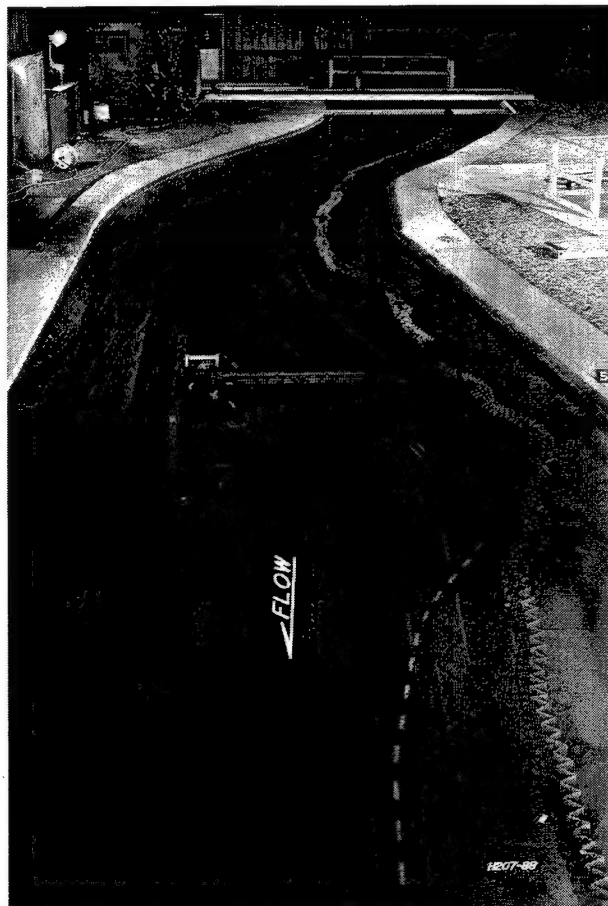




Photo 61. Plan C cofferdam, looking upstream; discharge 44,000 cfs; confetti showing surface current patterns through navigation pass

Photo 62. Plan C cofferdam, looking upstream; discharge 102,000 cfs; confetti showing surface current patterns through navigation pass



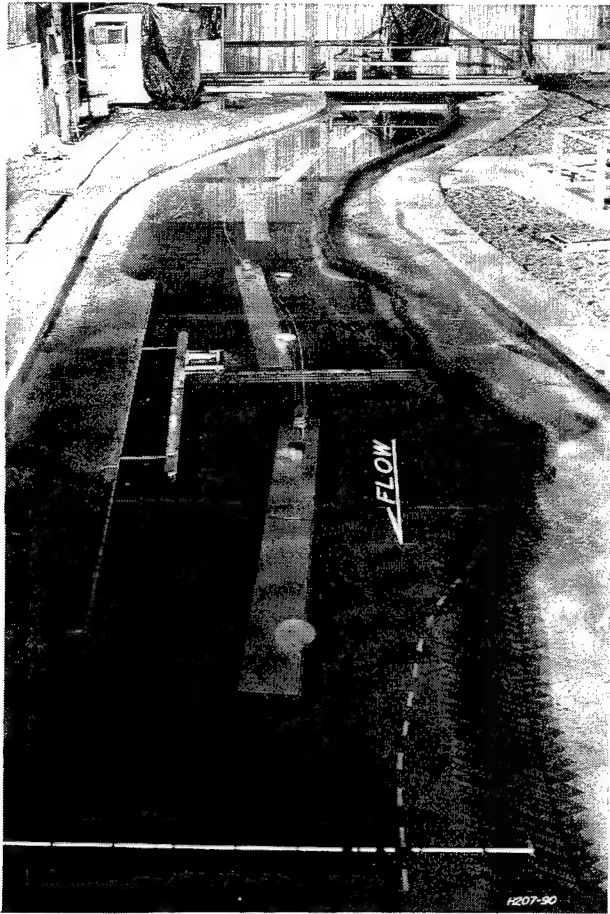
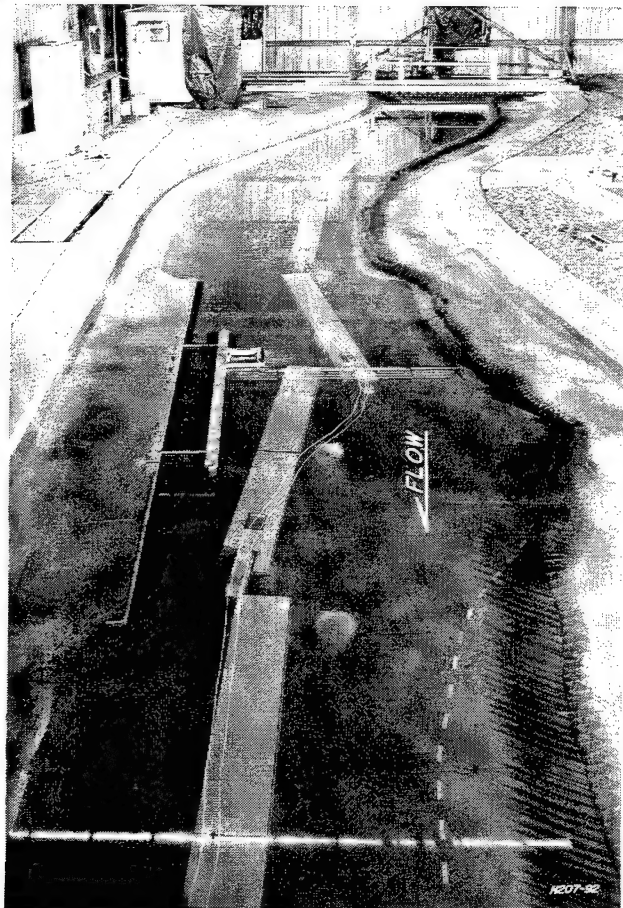


Photo 63. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock closed; showing path of downbound tow navigating the reach. Note tow navigating bend upstream of the dam along the left channel limits

Photo 64. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock closed; showing path of upbound tow navigating the reach. Note increase in maneuvering required compared with lock open



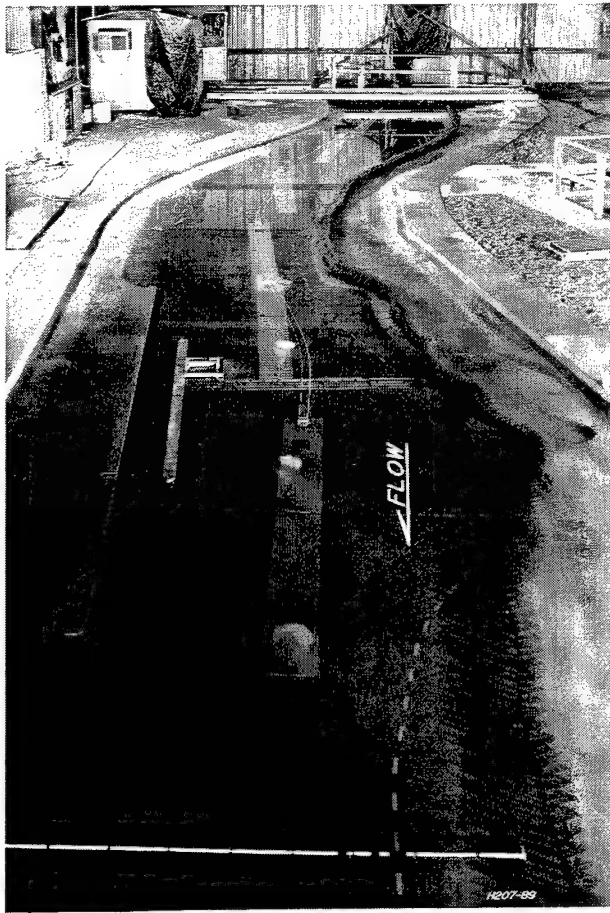


Photo 65. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock open as floodway; showing path of downbound tow navigating the reach. Note tow navigating bend upstream of dam along the left channel limits

Photo 66. Plan C cofferdam, looking upstream; discharge 20,000 cfs; lock open as floodway; showing path of upbound tow navigating the reach

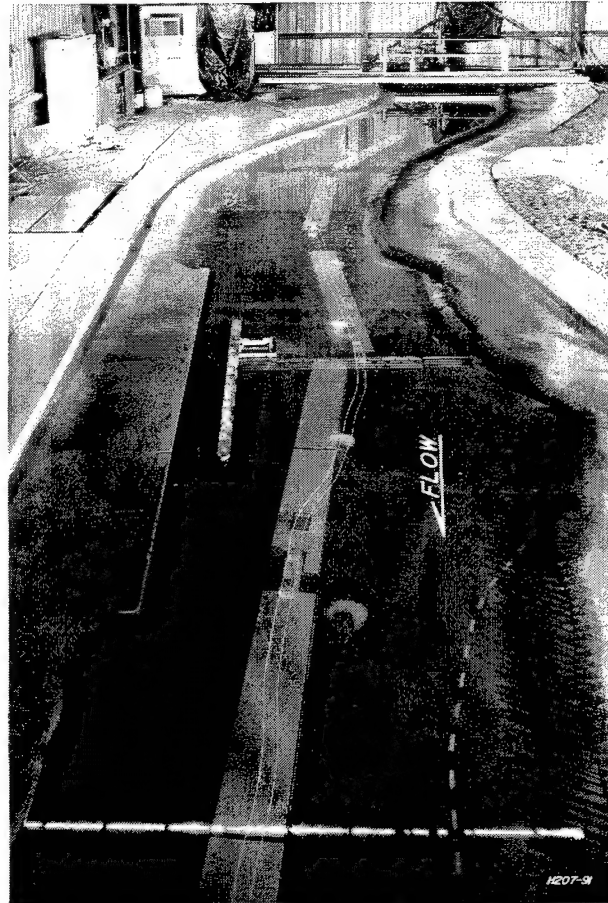




Photo 67. Plan C cofferdam, looking upstream; discharge 44,000 cfs; showing path of downbound tow navigating the reach

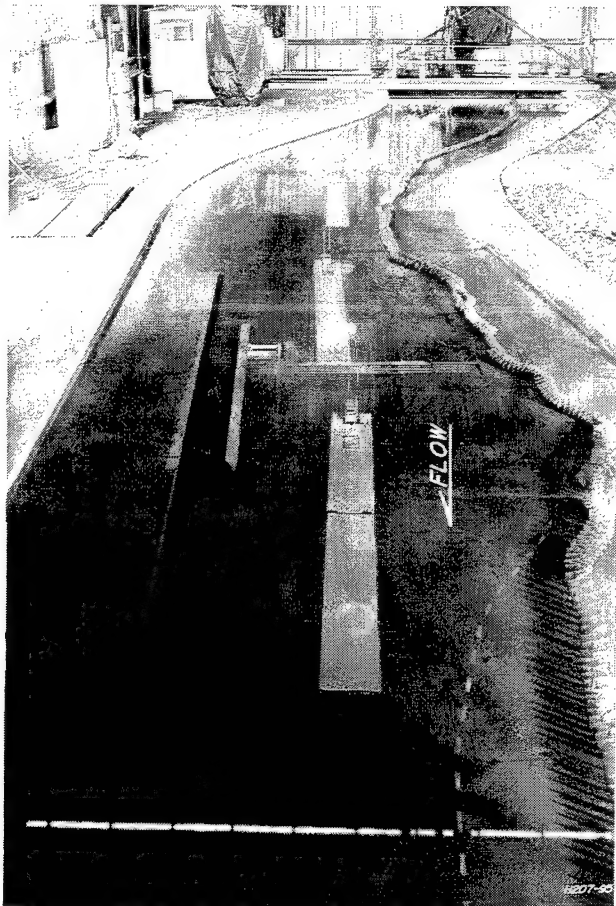


Photo 68. Plan C cofferdam, looking upstream; discharge 102,000 cfs; showing path of downbound tow navigating the reach

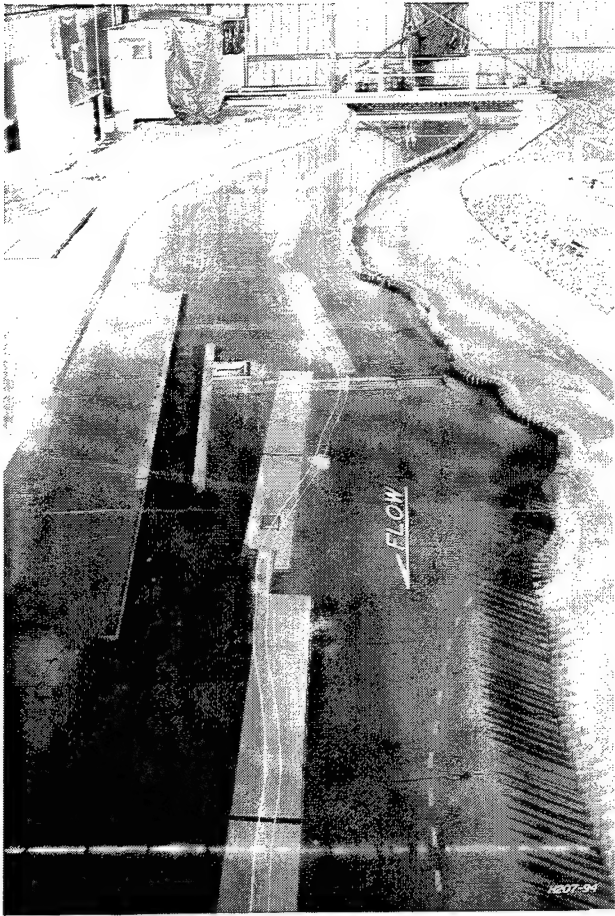


Photo 69. Plan C cofferdam, looking upstream; discharge 44,000 cfs; showing path of upbound tow navigating the reach. Note maneuvering required to move through the navigation pass

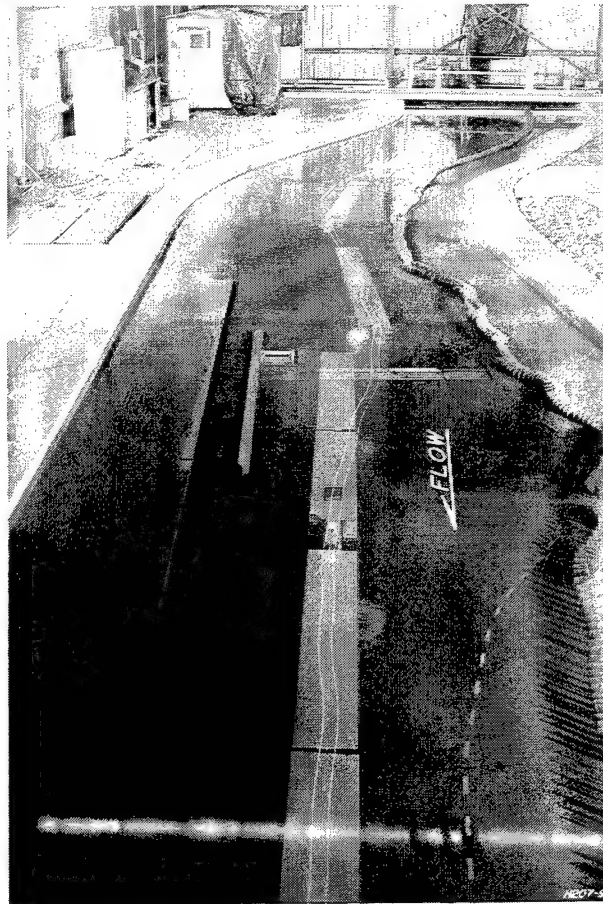


Photo 70. Plan C cofferdam, looking upstream; discharge 102,000 cfs; showing path of upbound tow navigating the reach

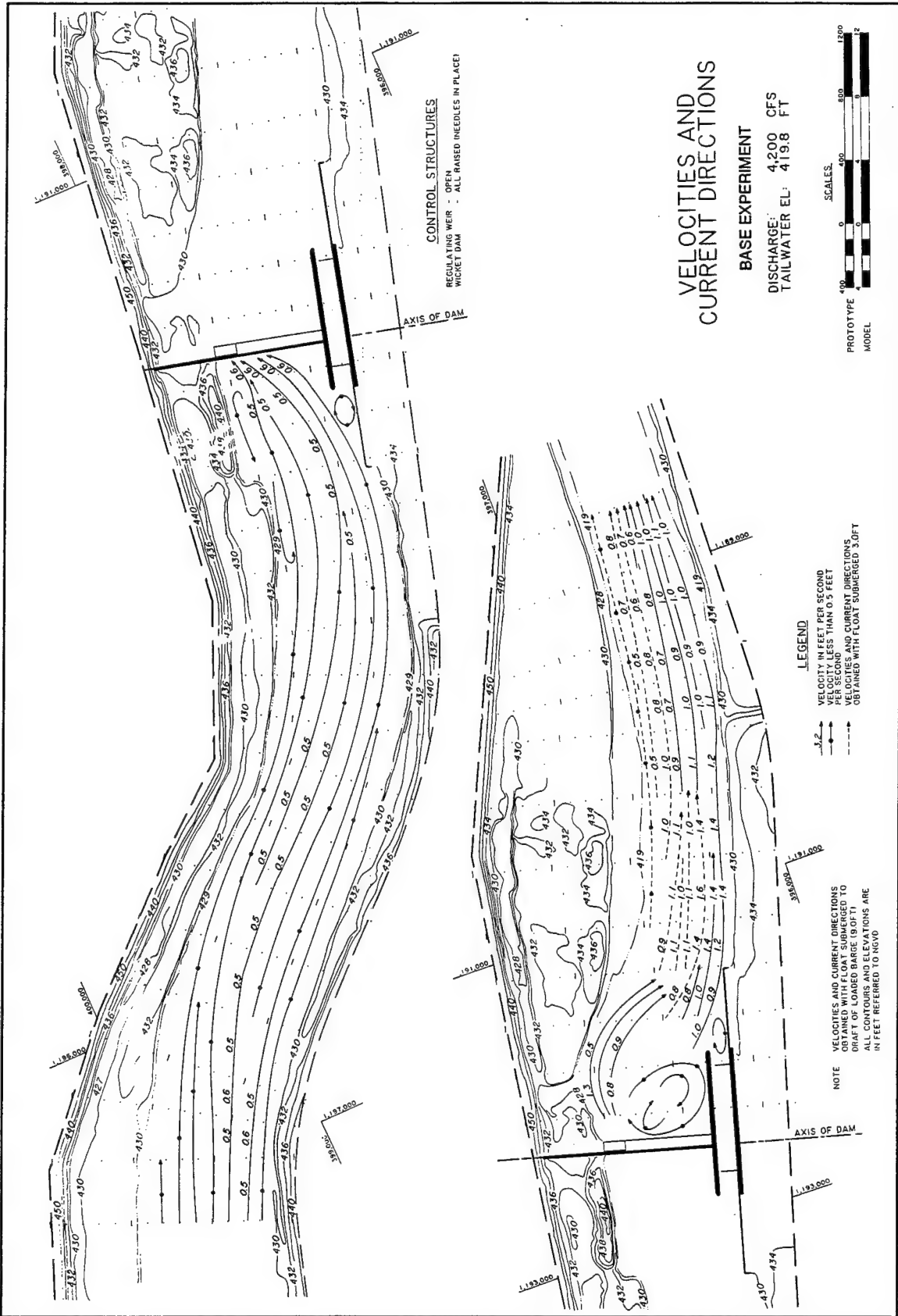


Plate 1

Plate 2

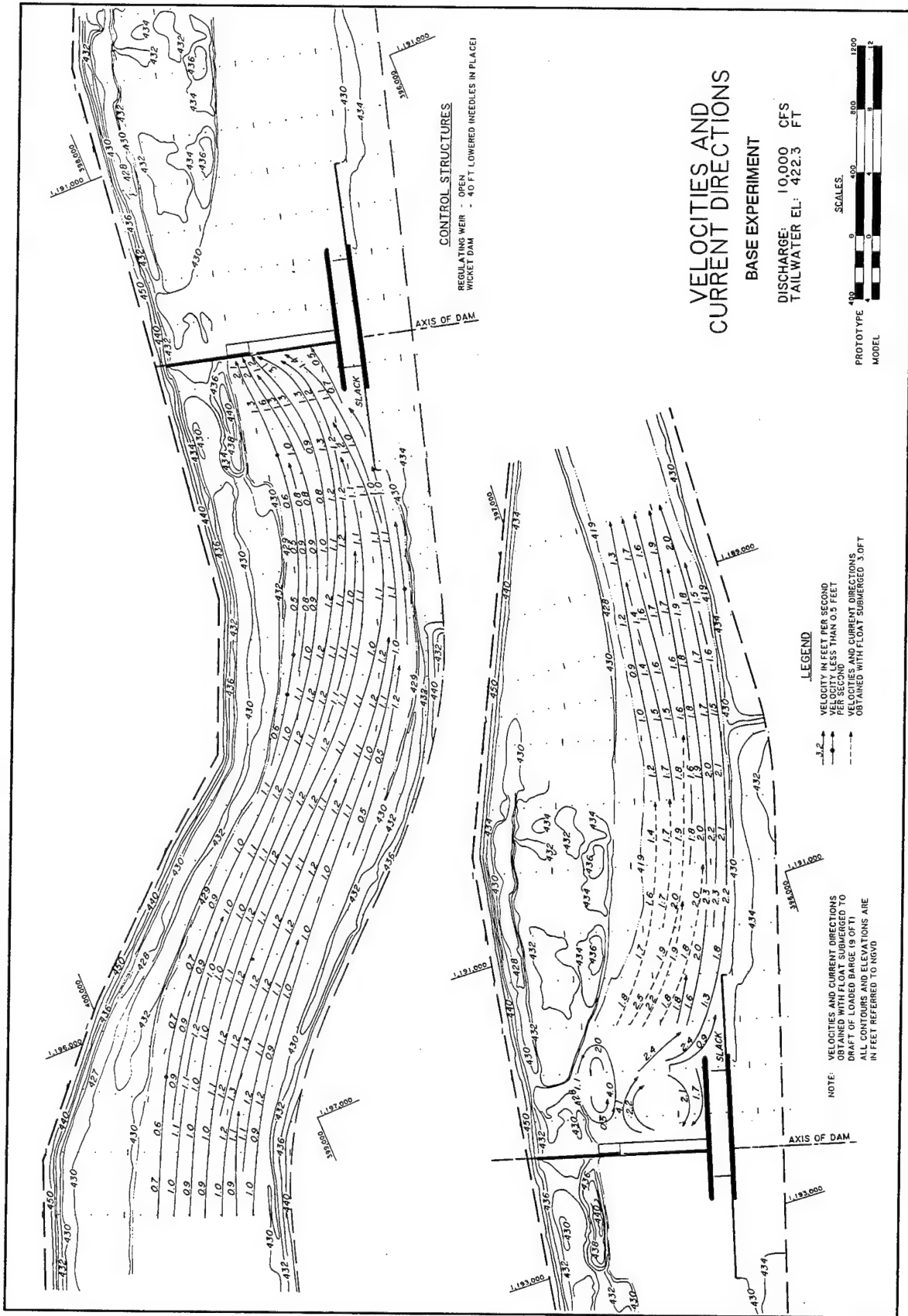
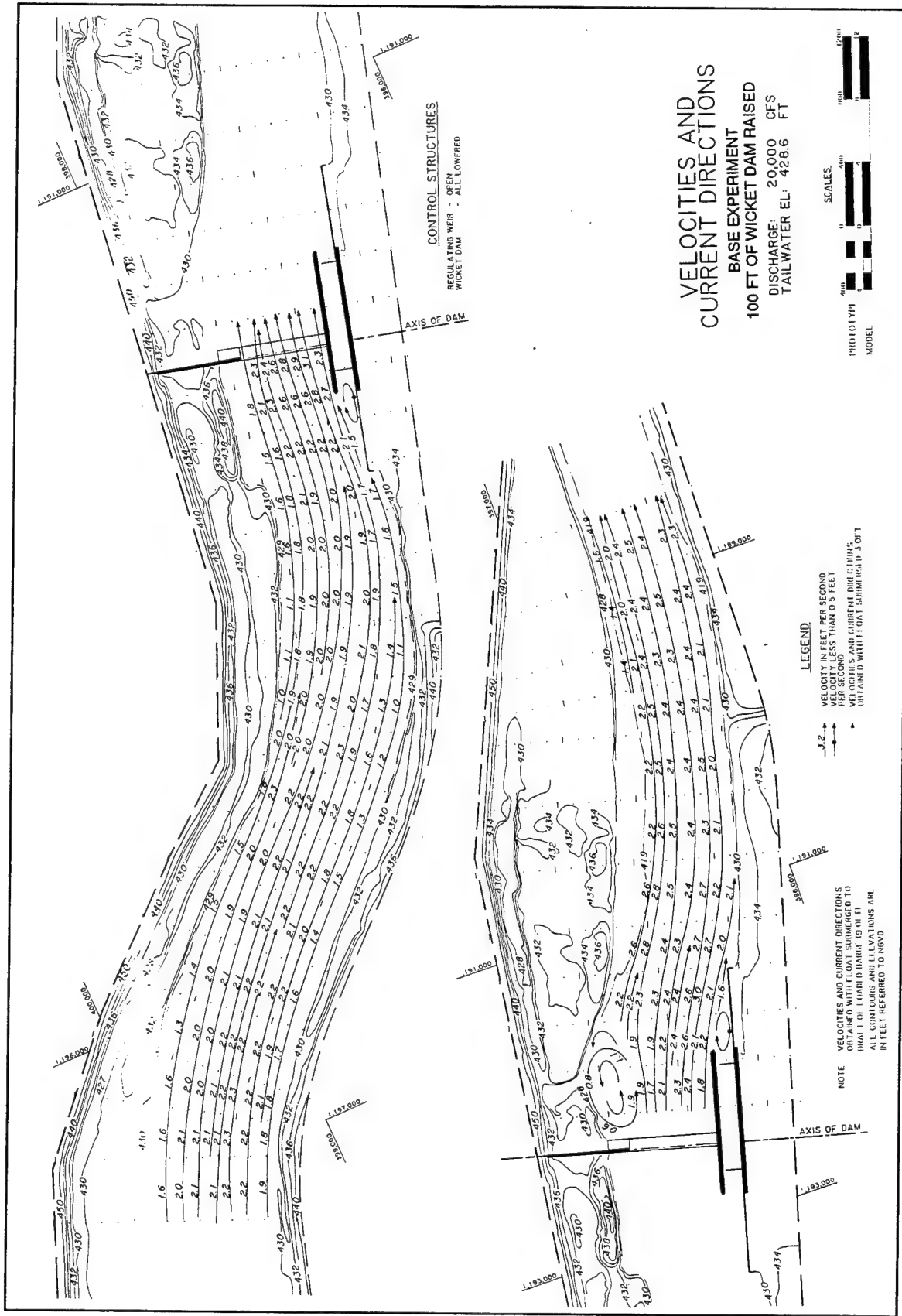


Plate 4



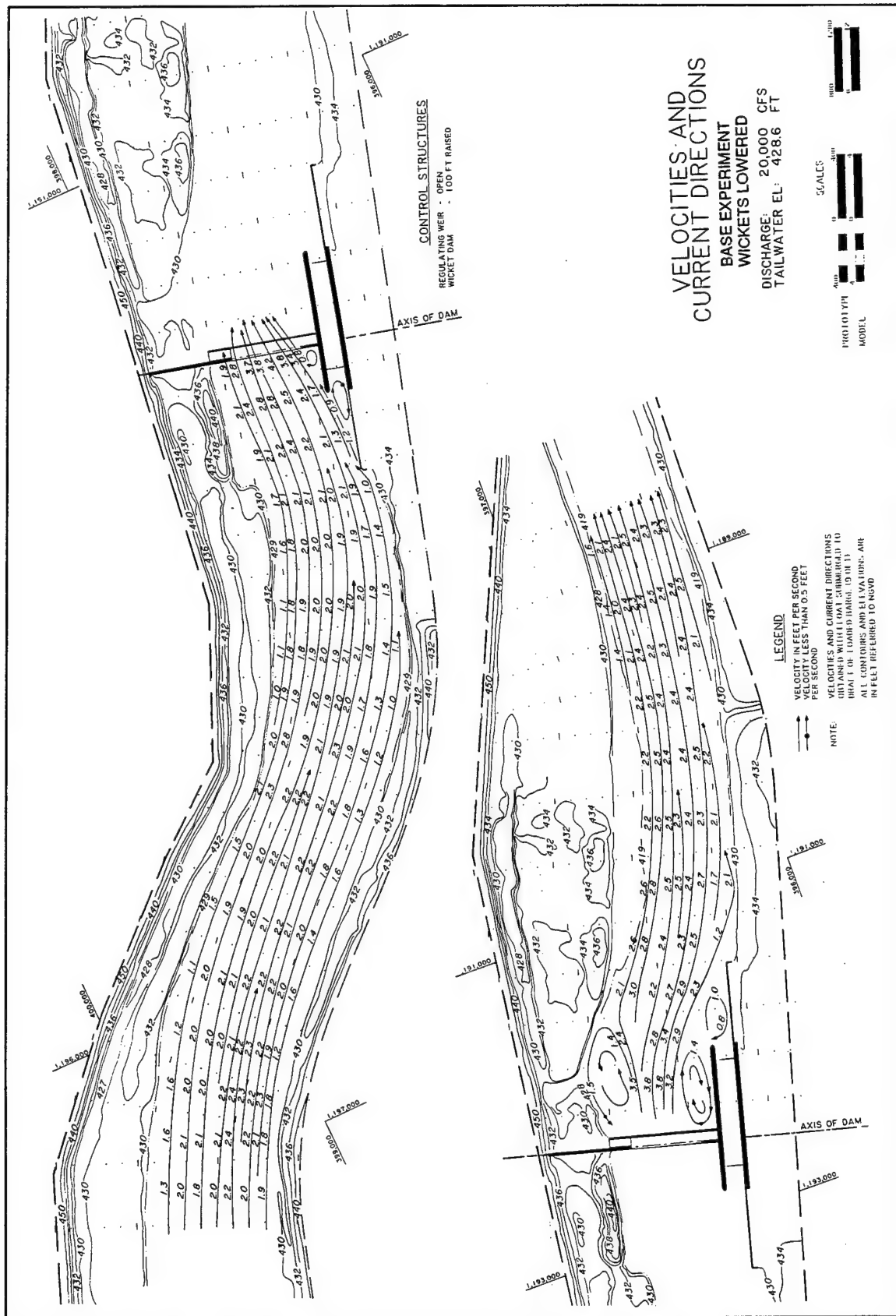
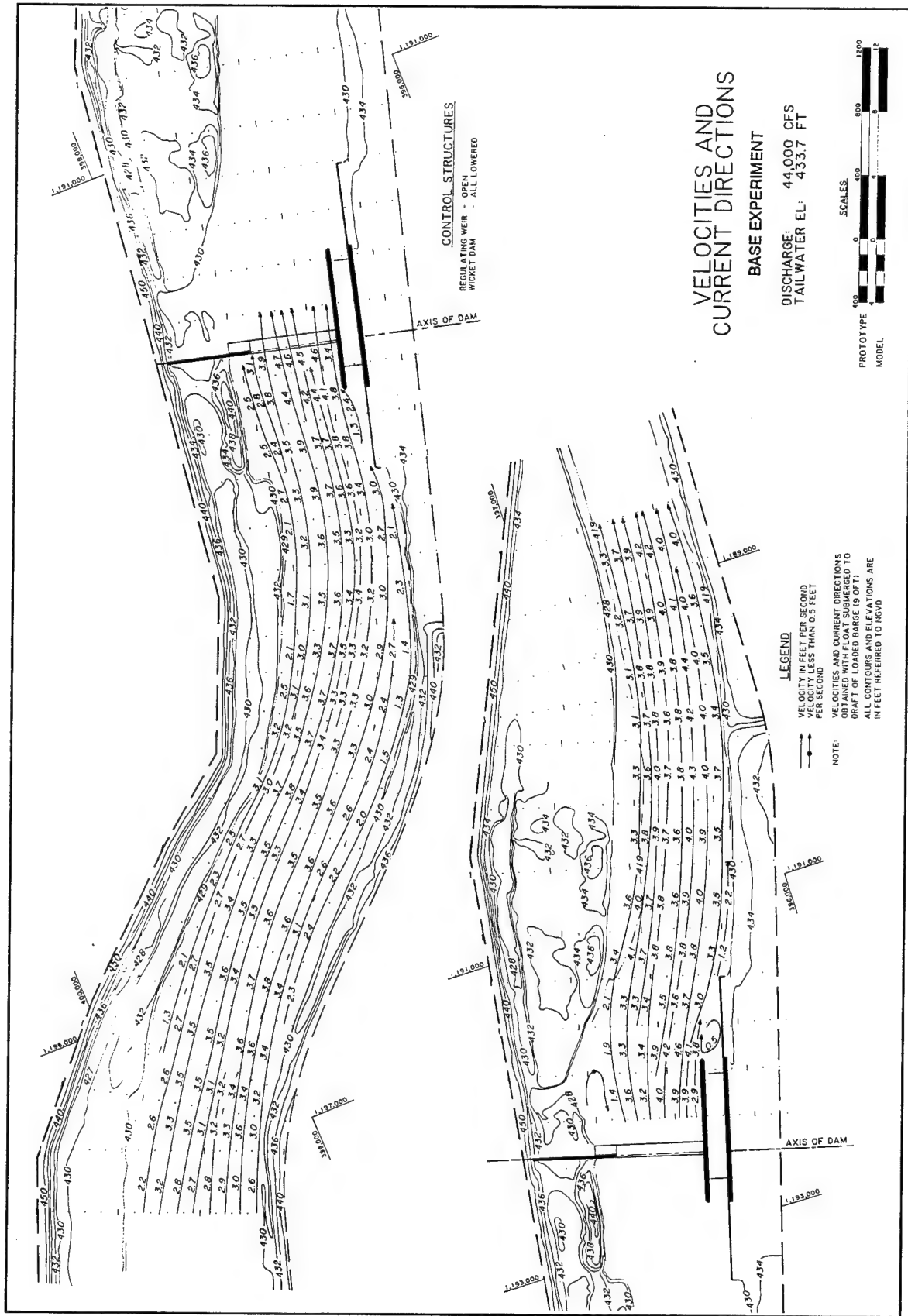
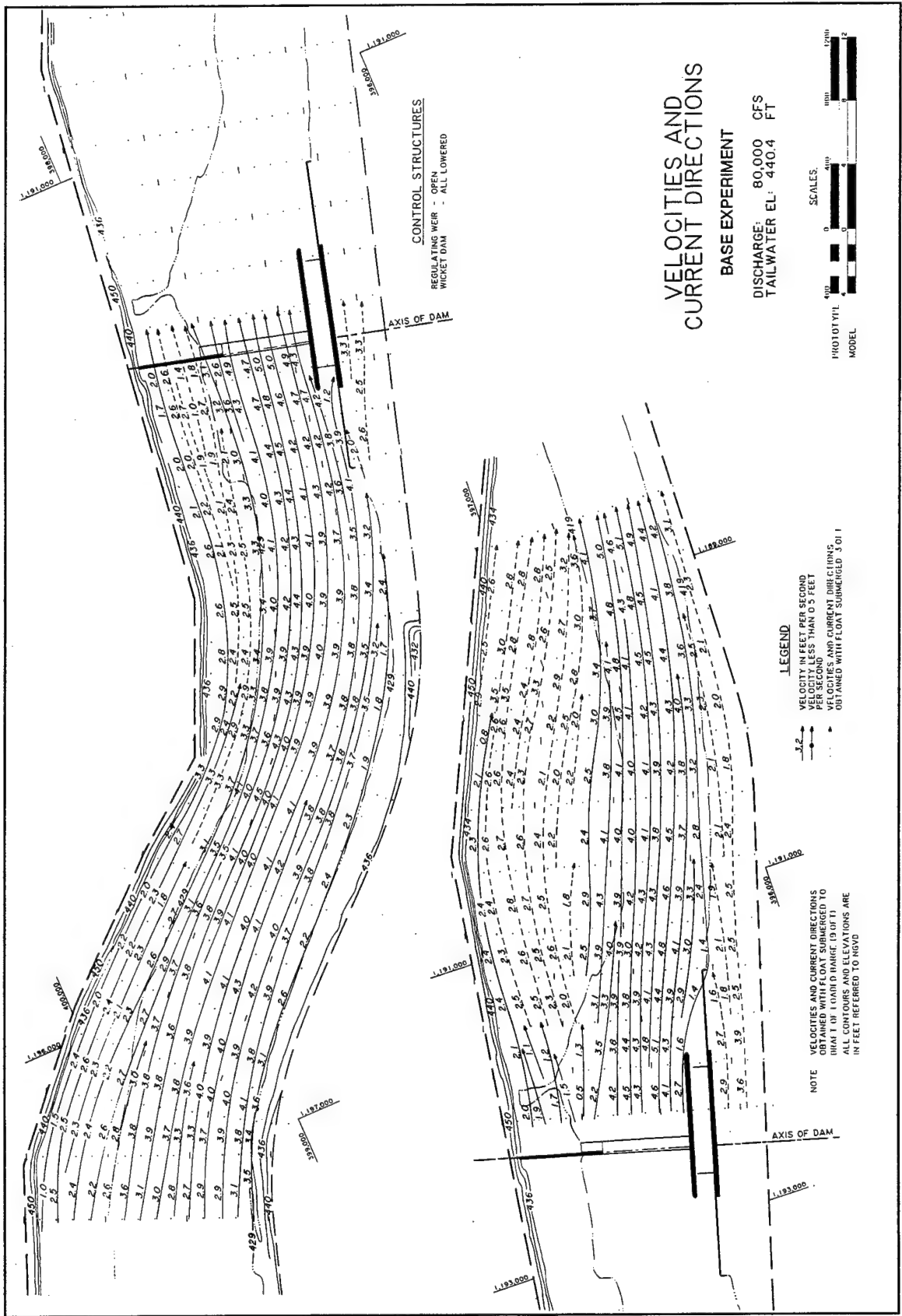


Plate 5

Plate 6





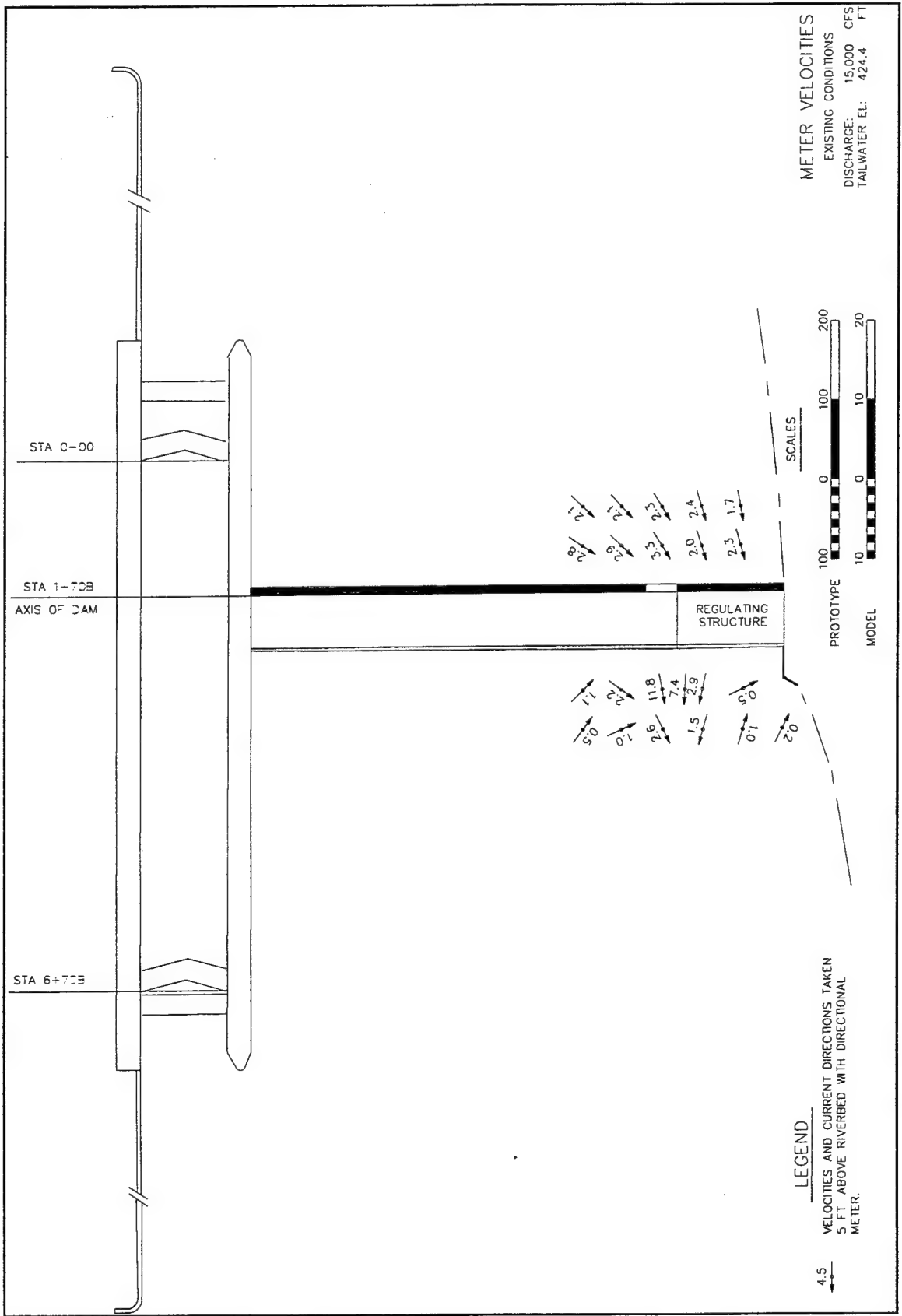


Plate 9

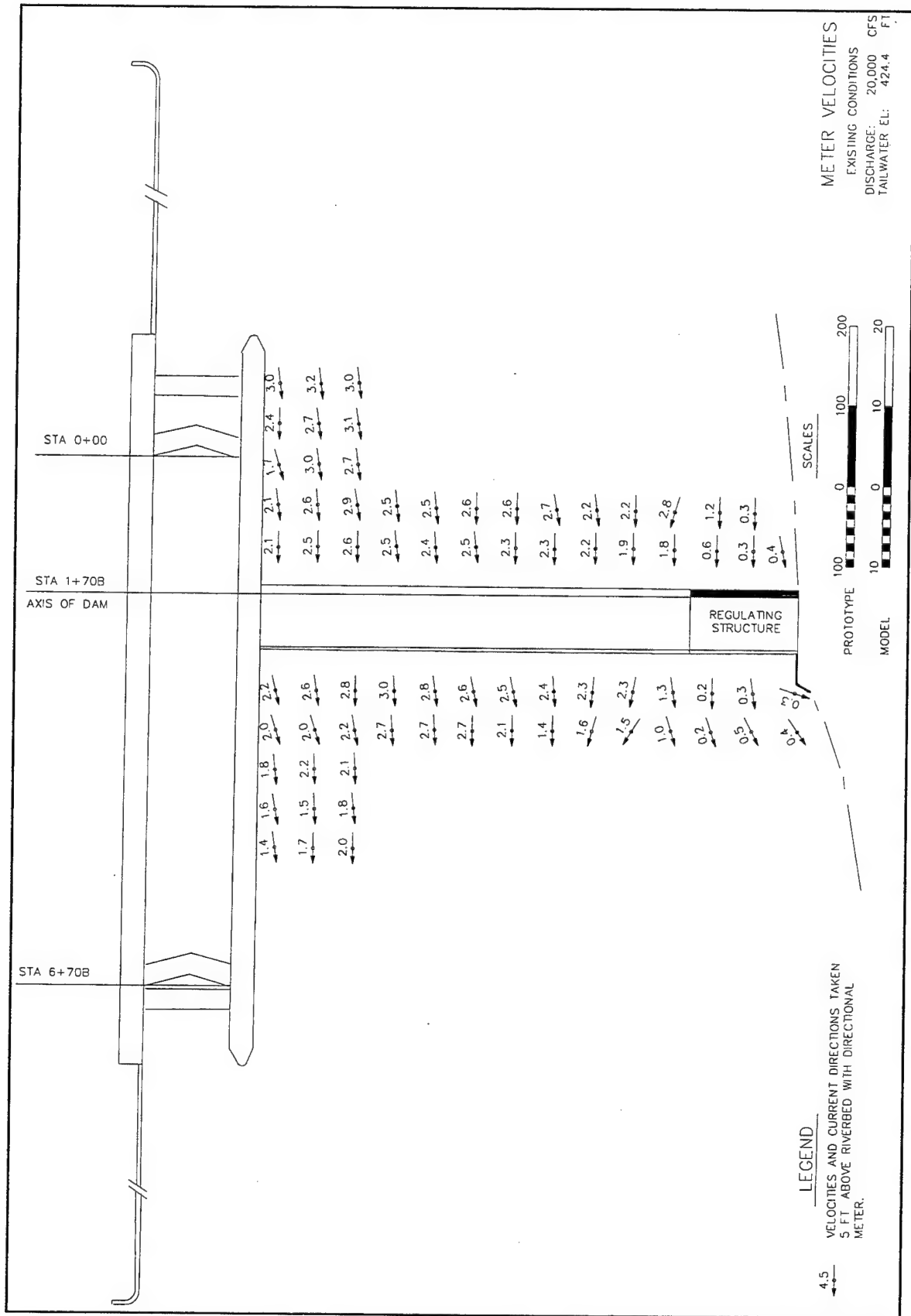
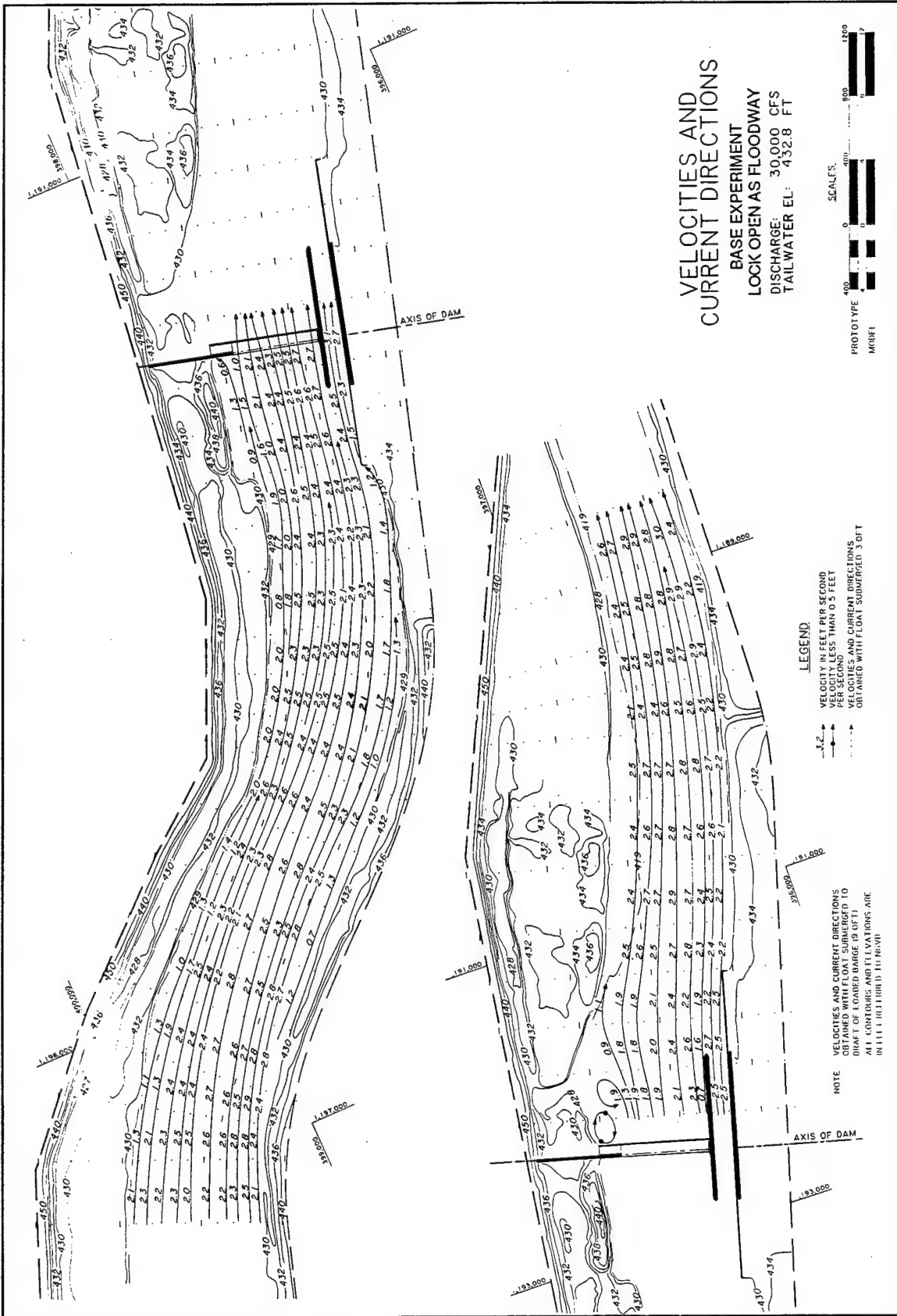


Plate 10



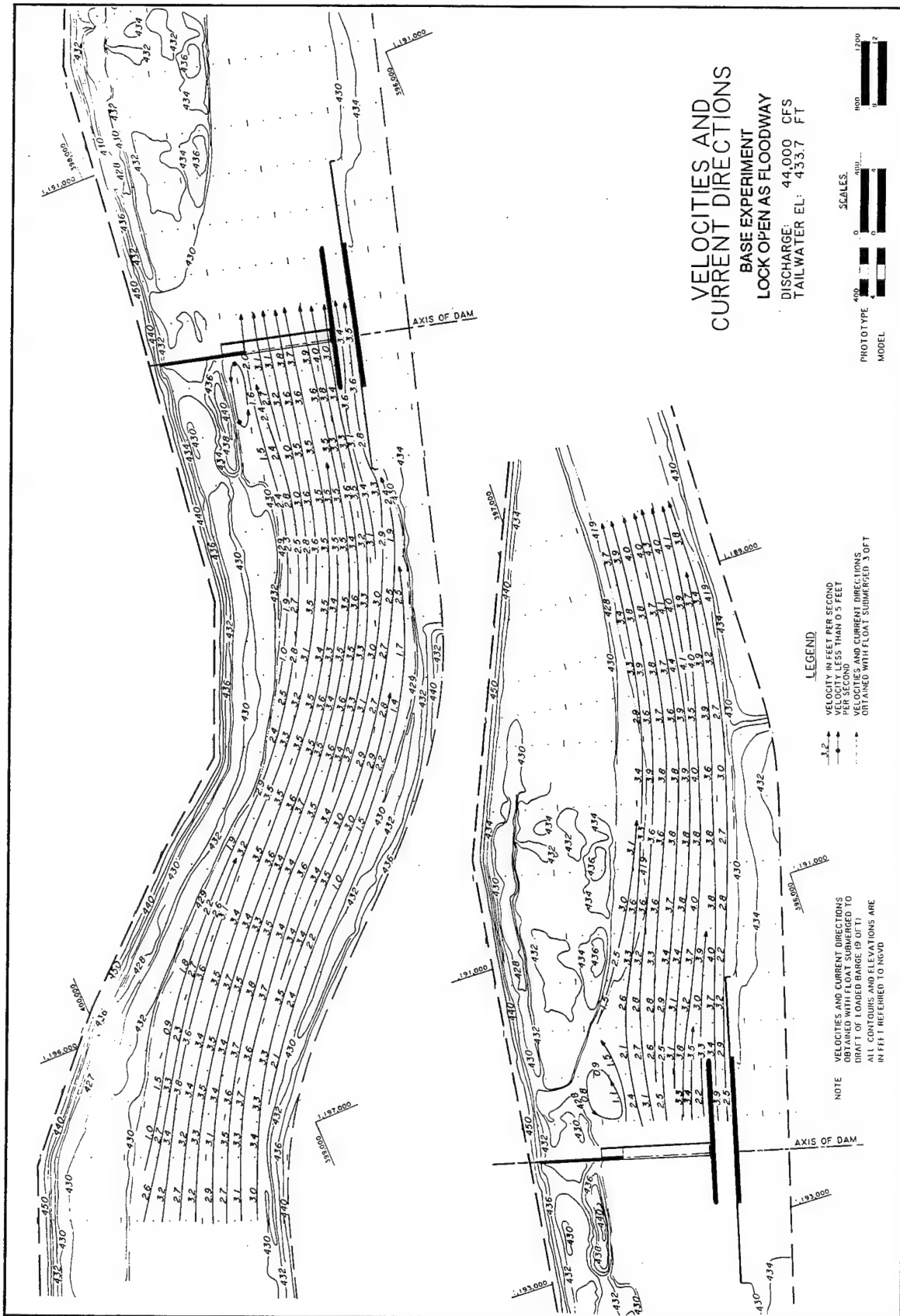


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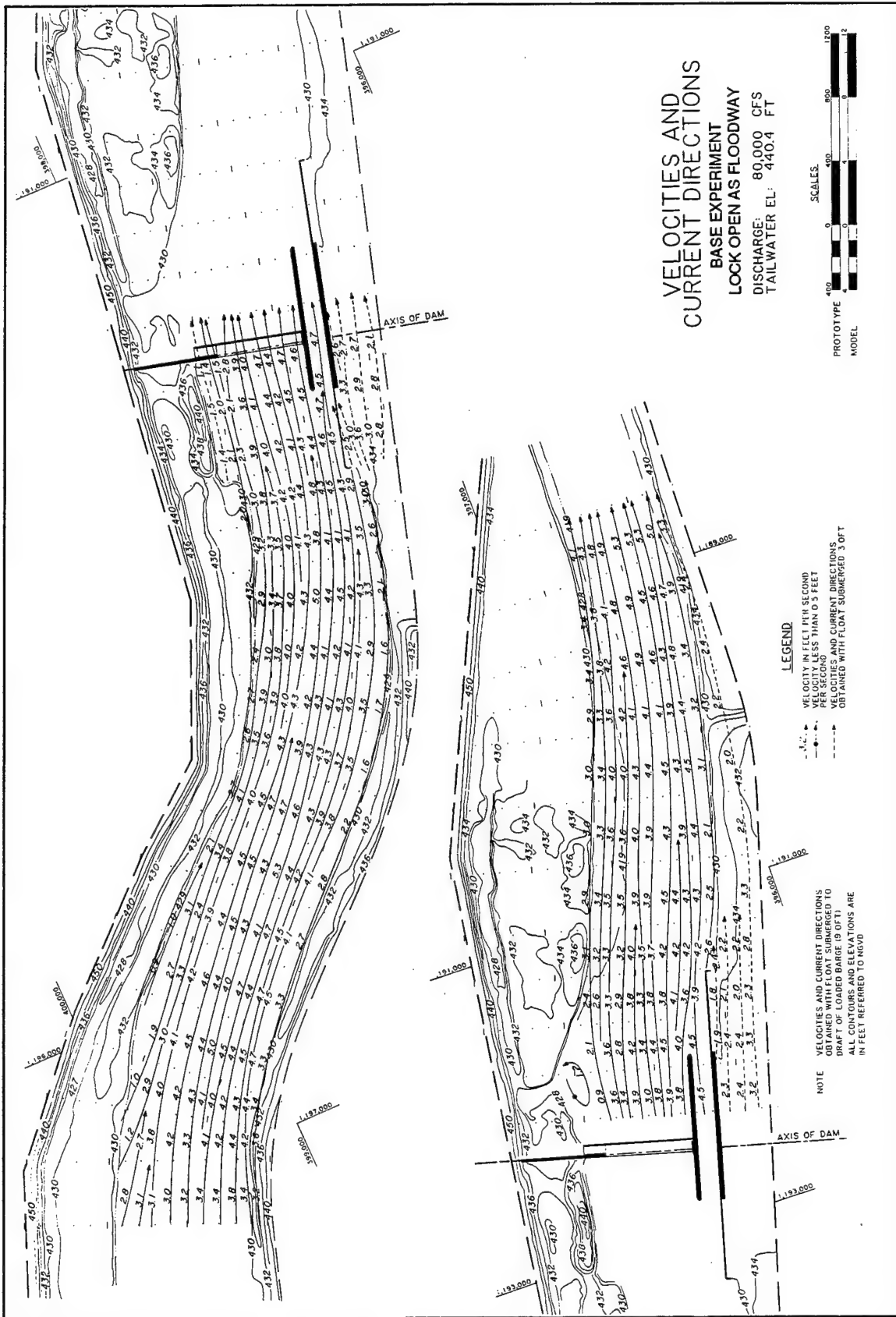


Plate 13

Plate 14

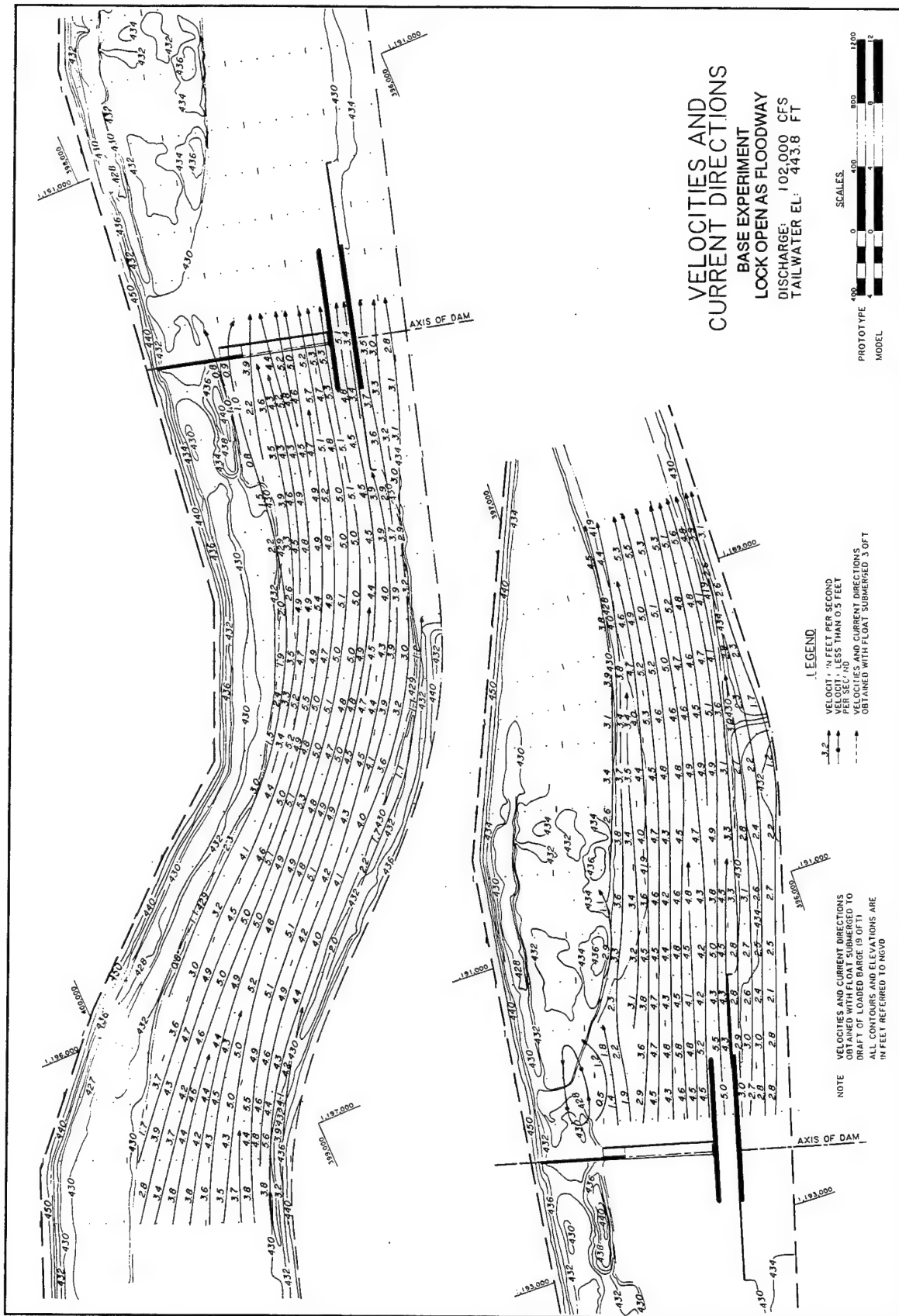
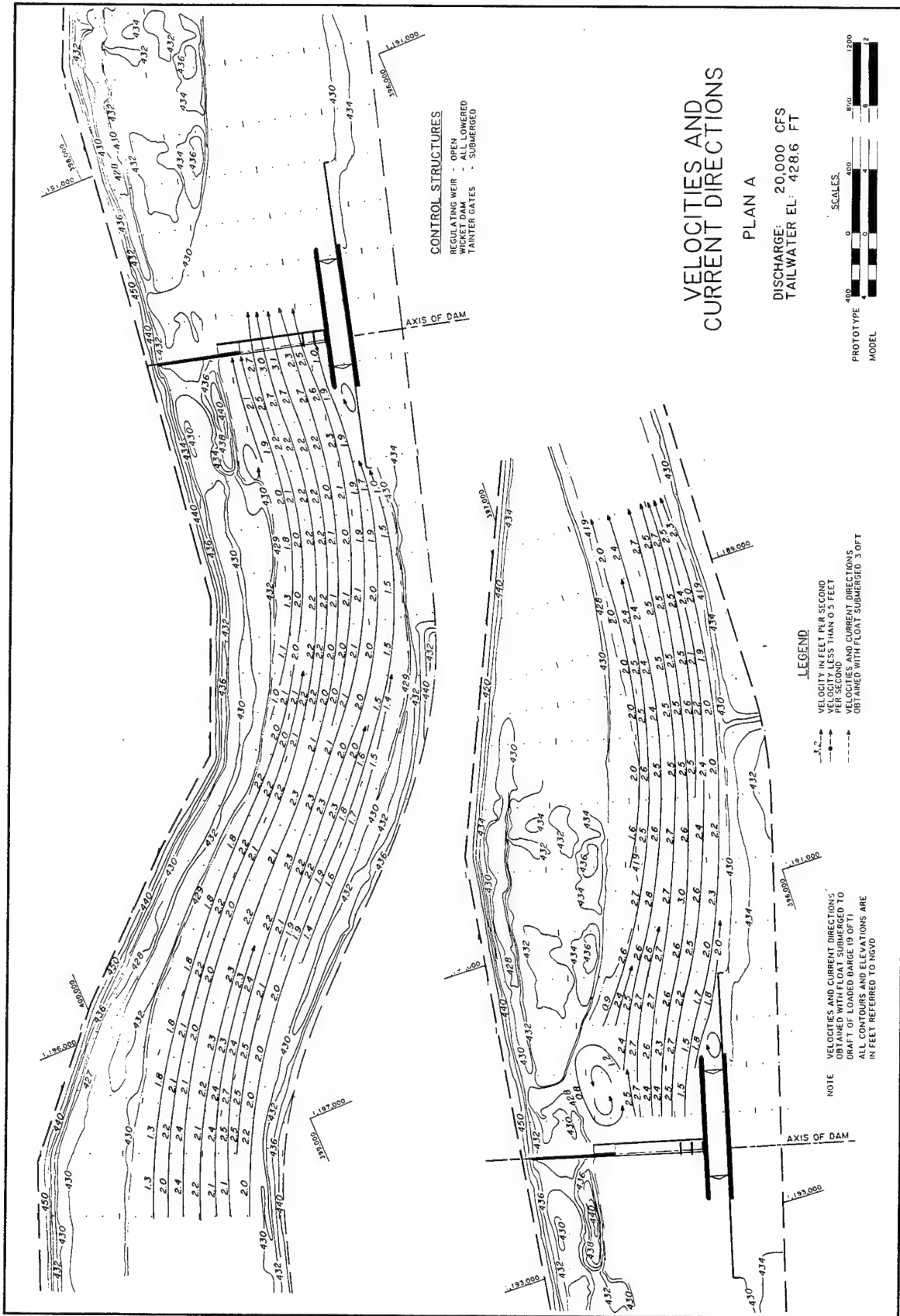
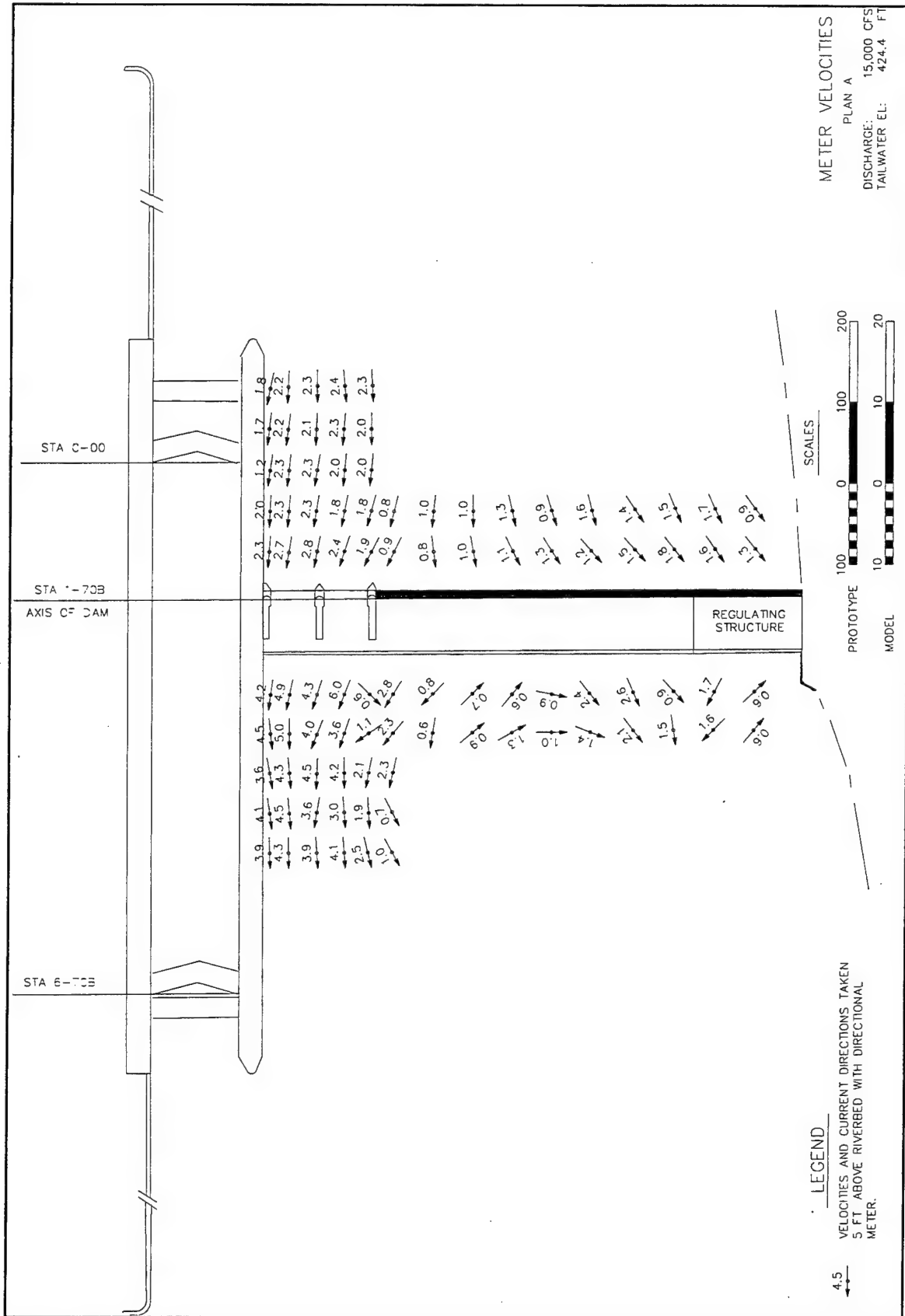




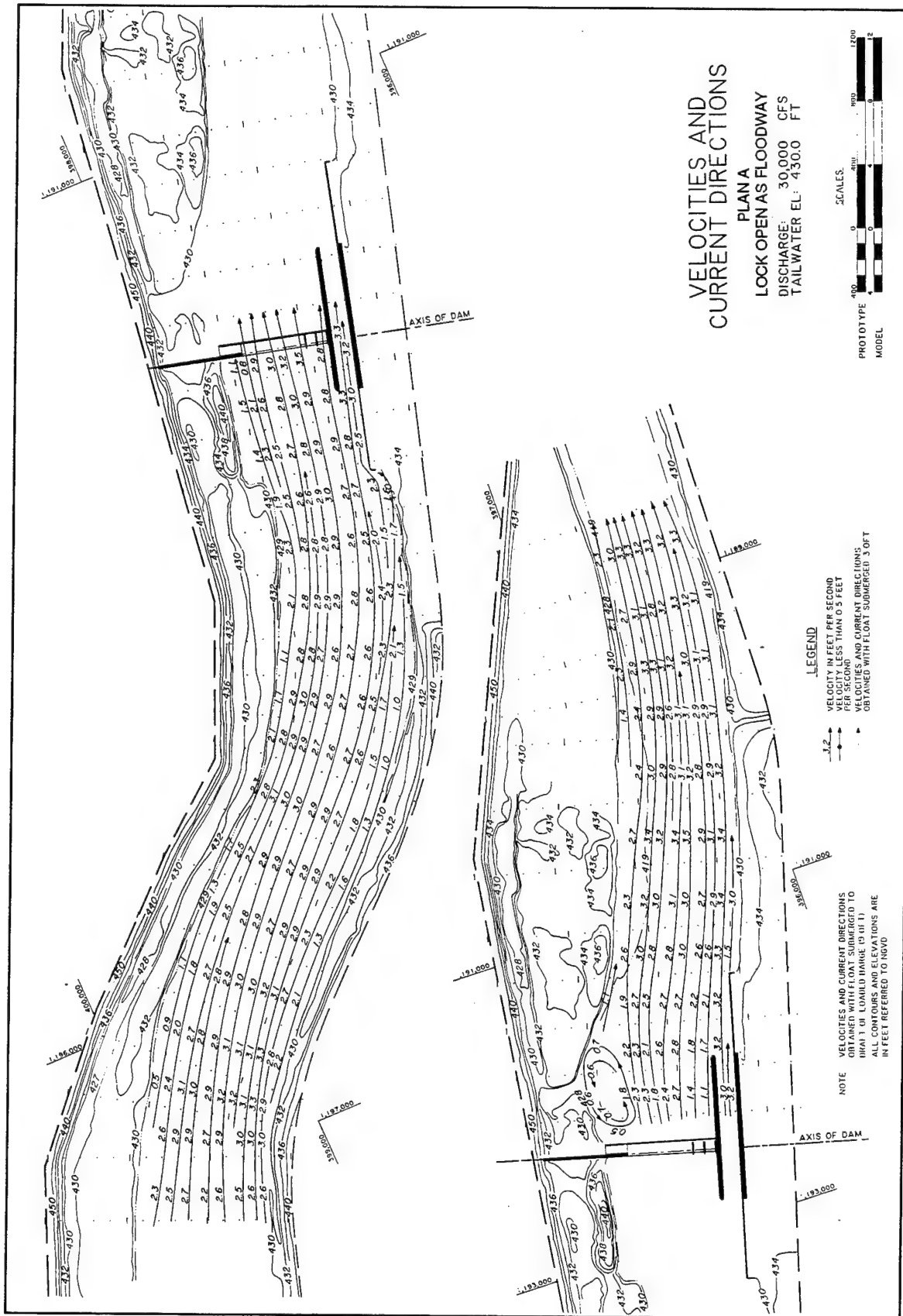
Plate 16

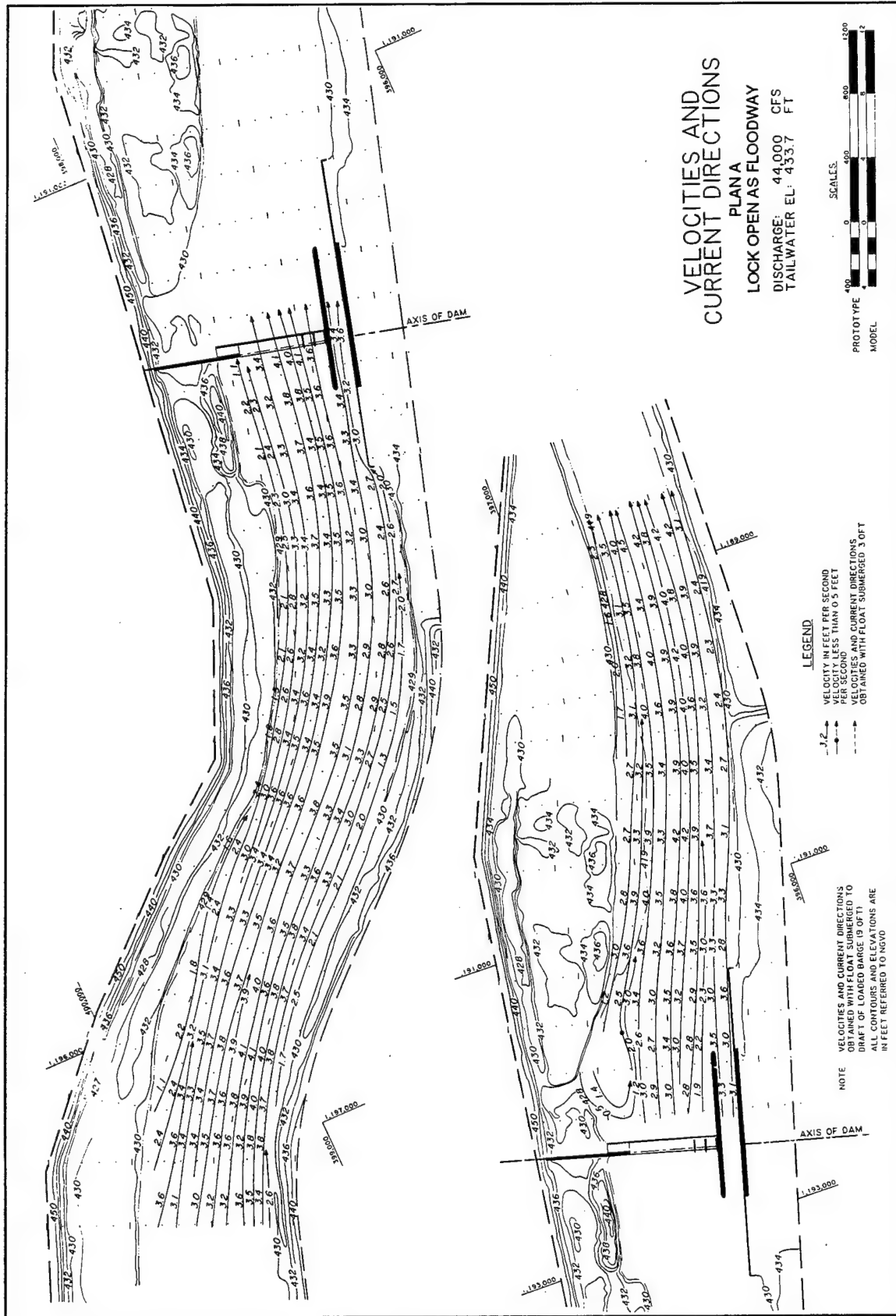


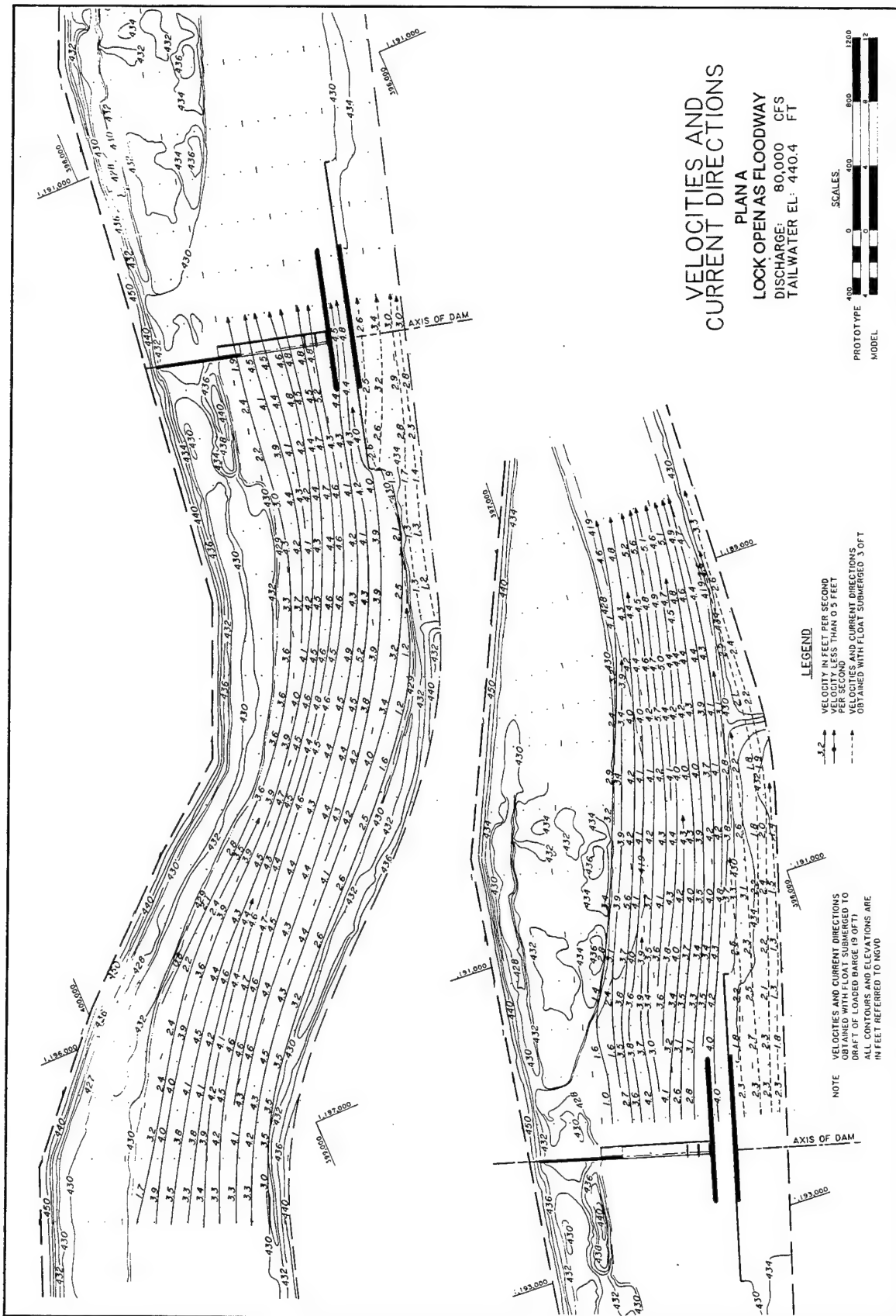


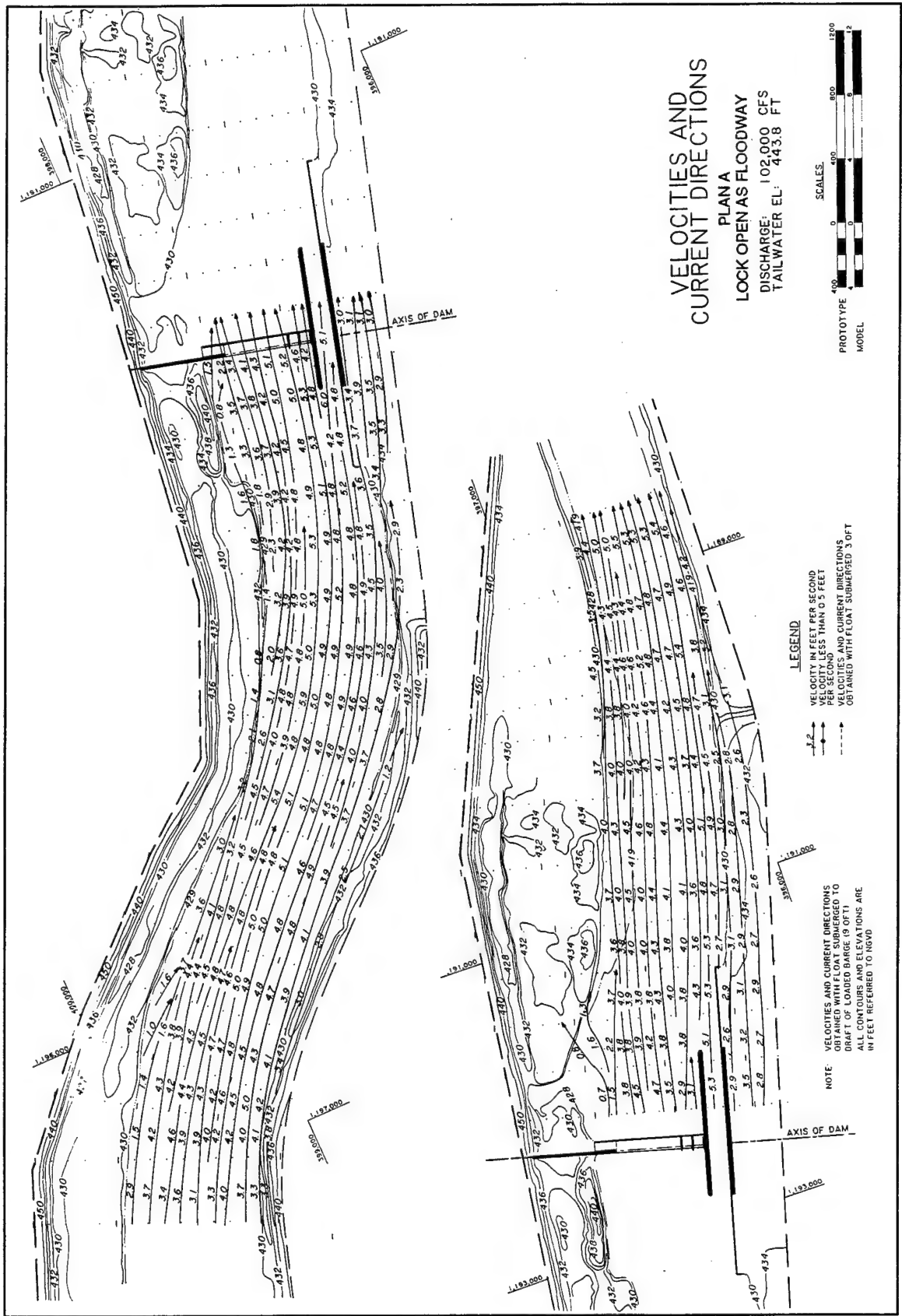


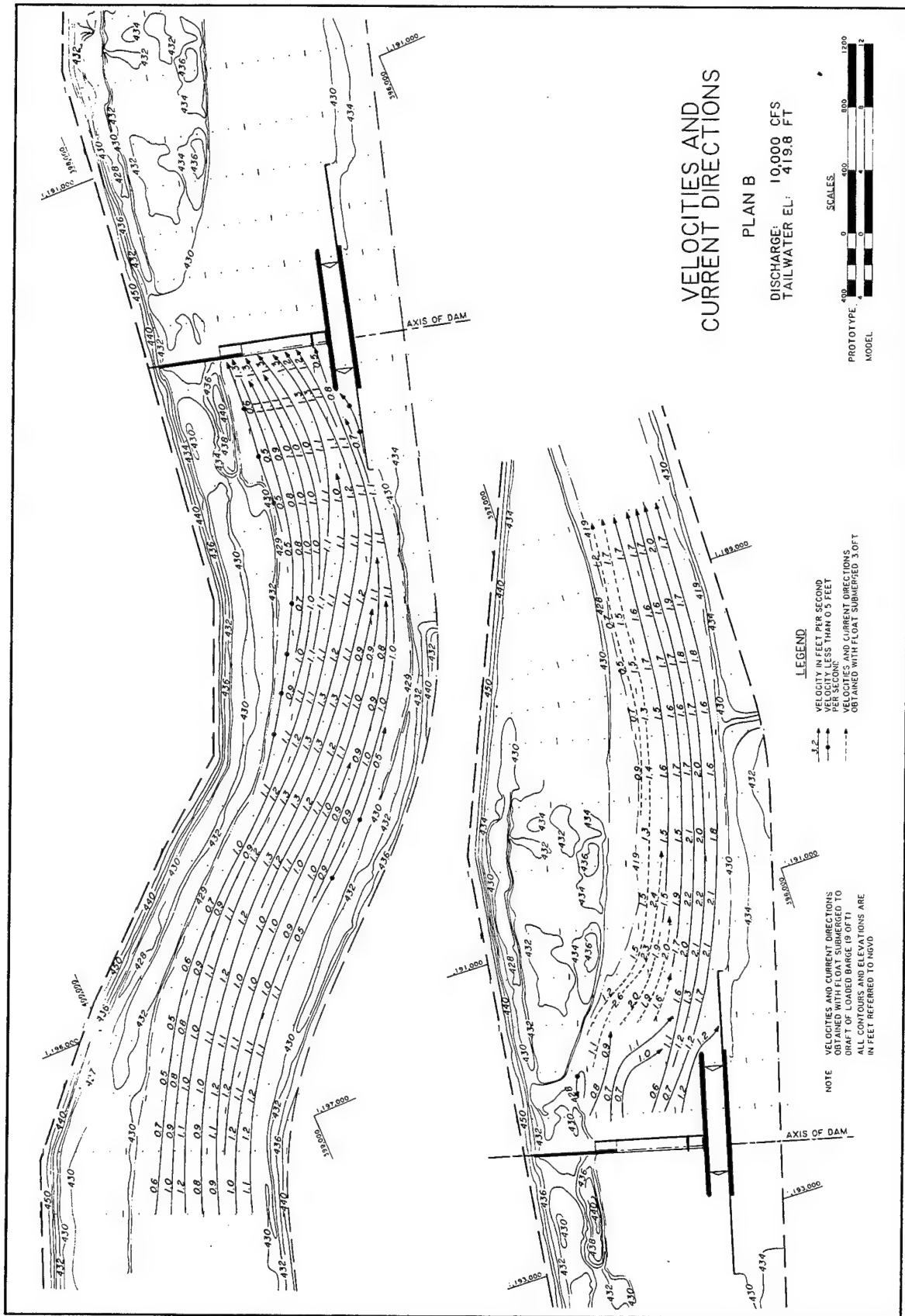


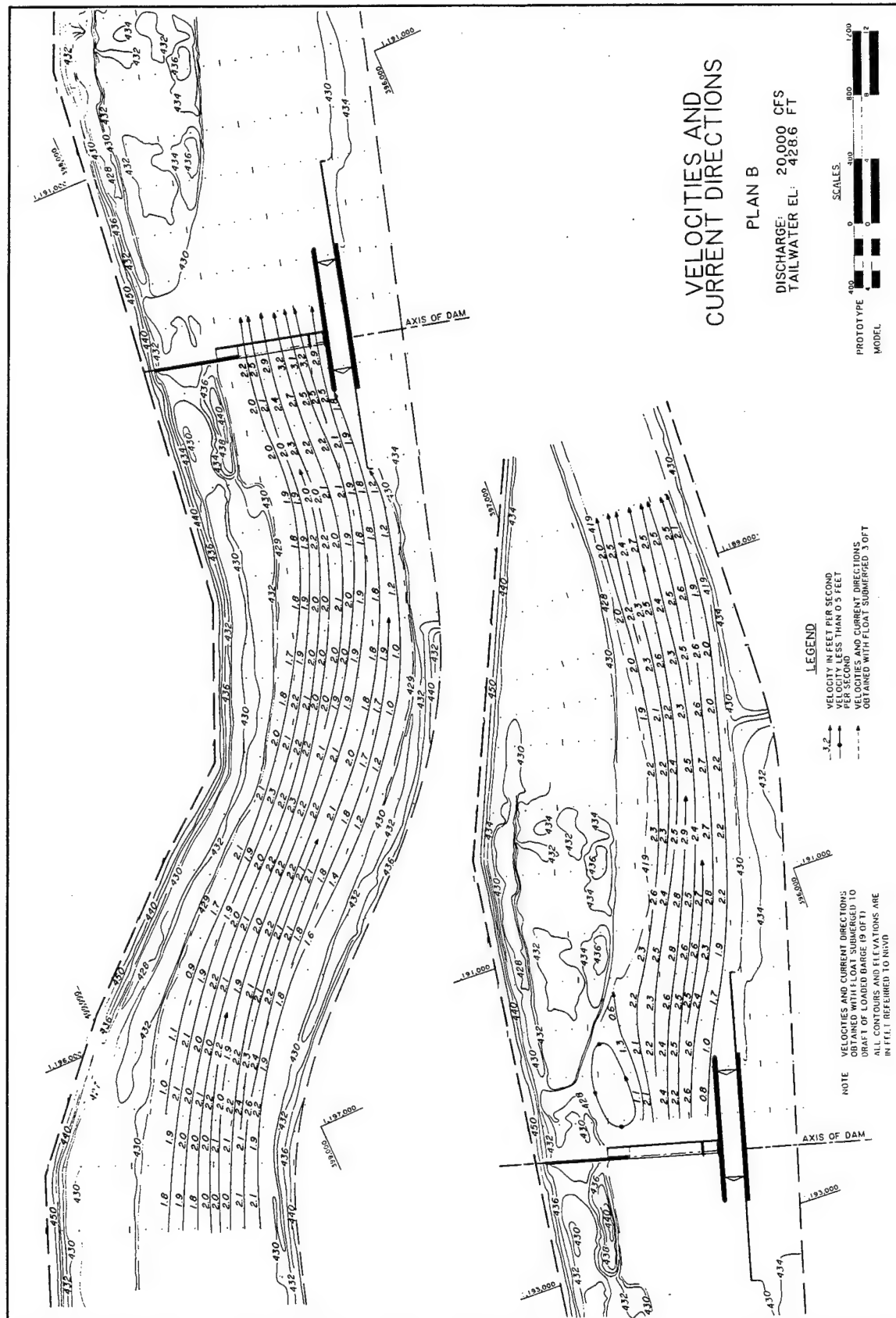


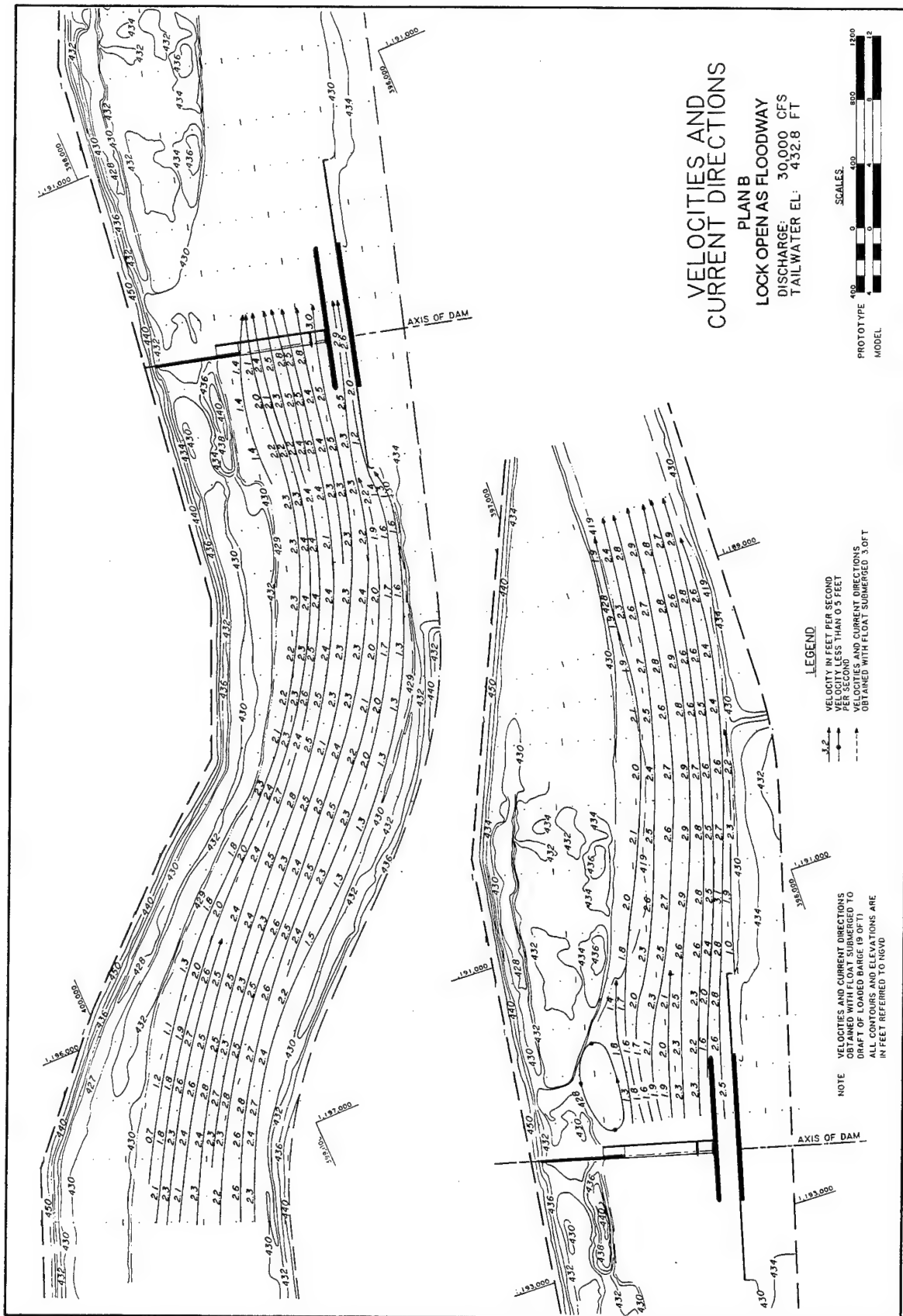












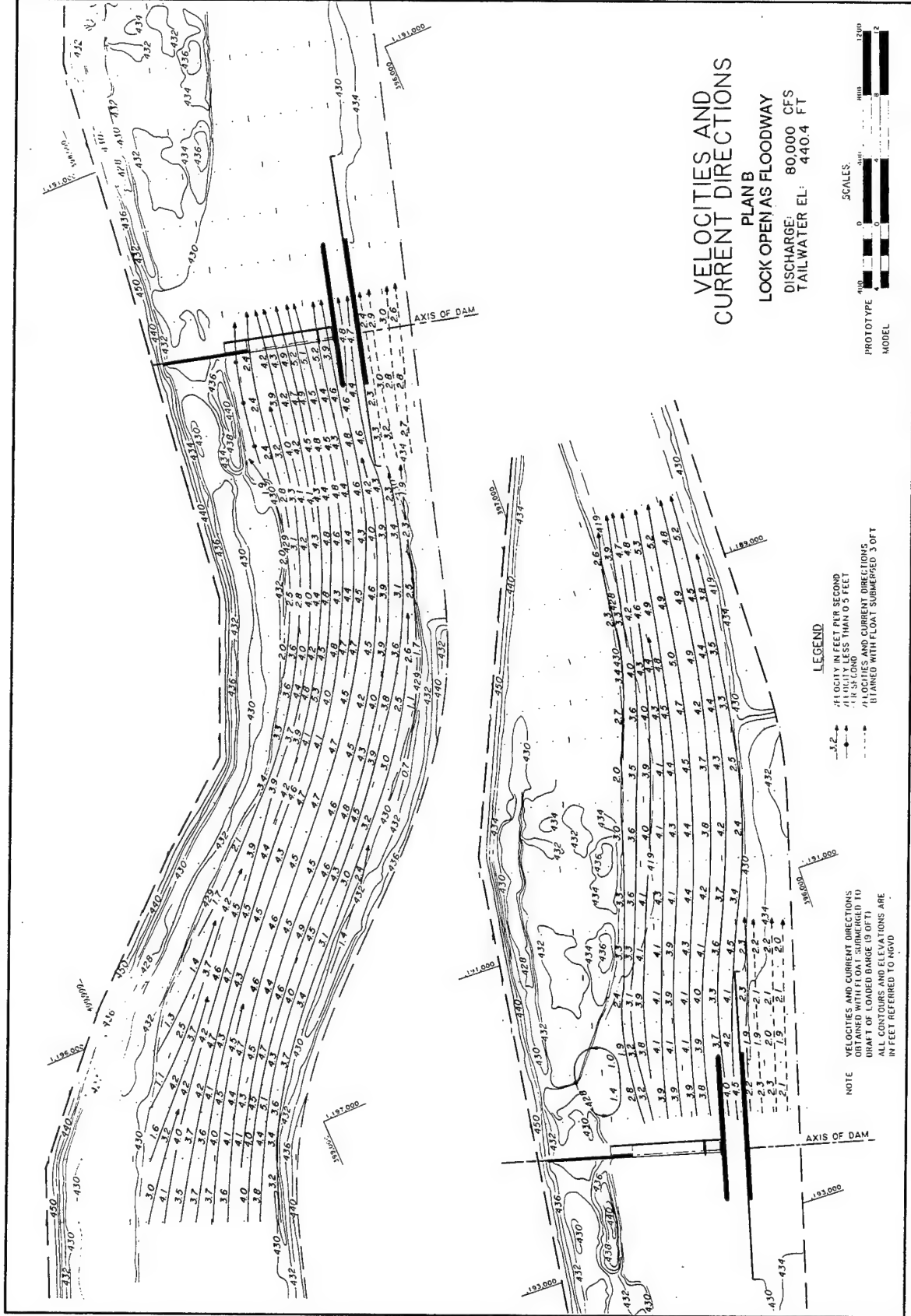


Plate 30



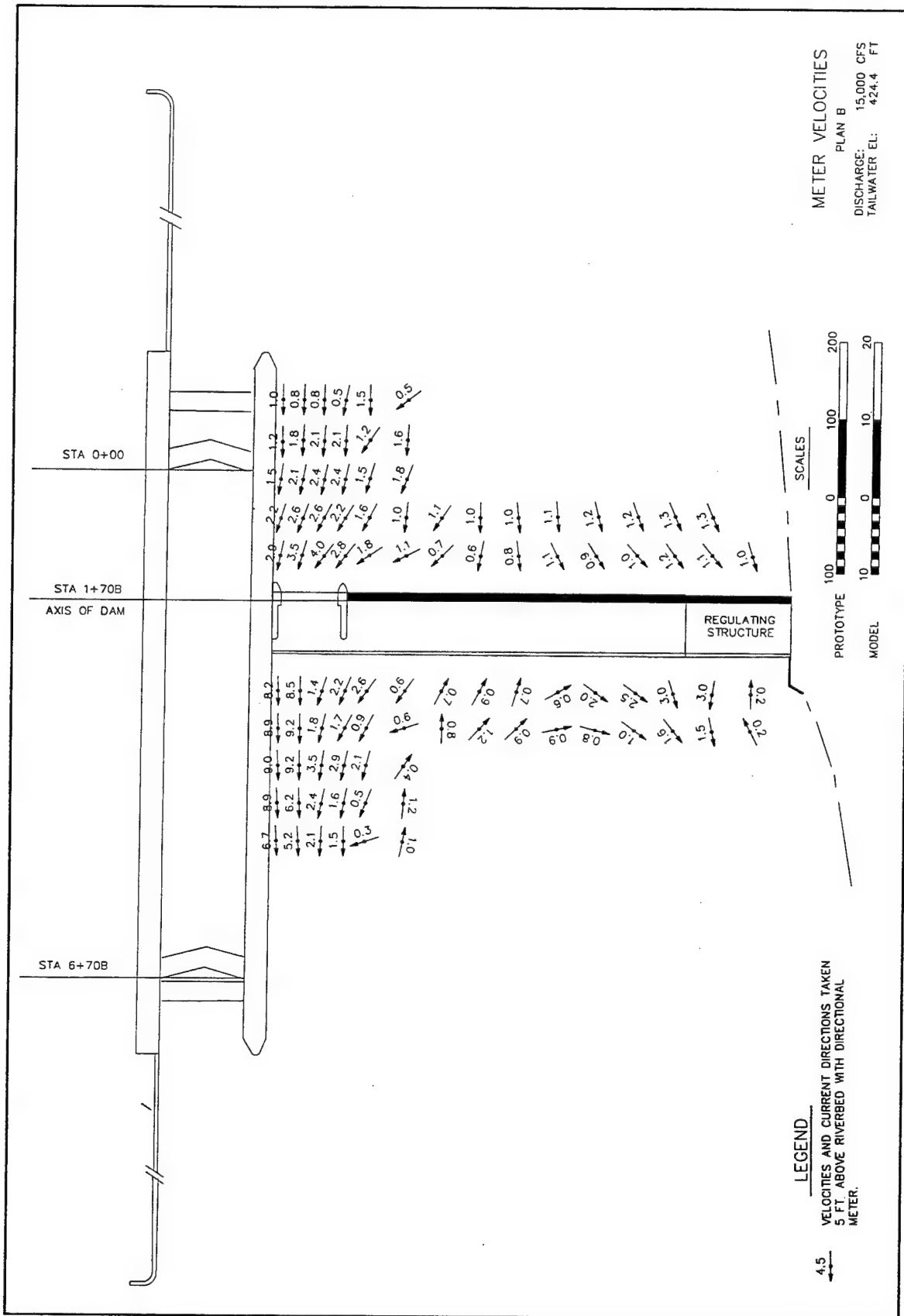
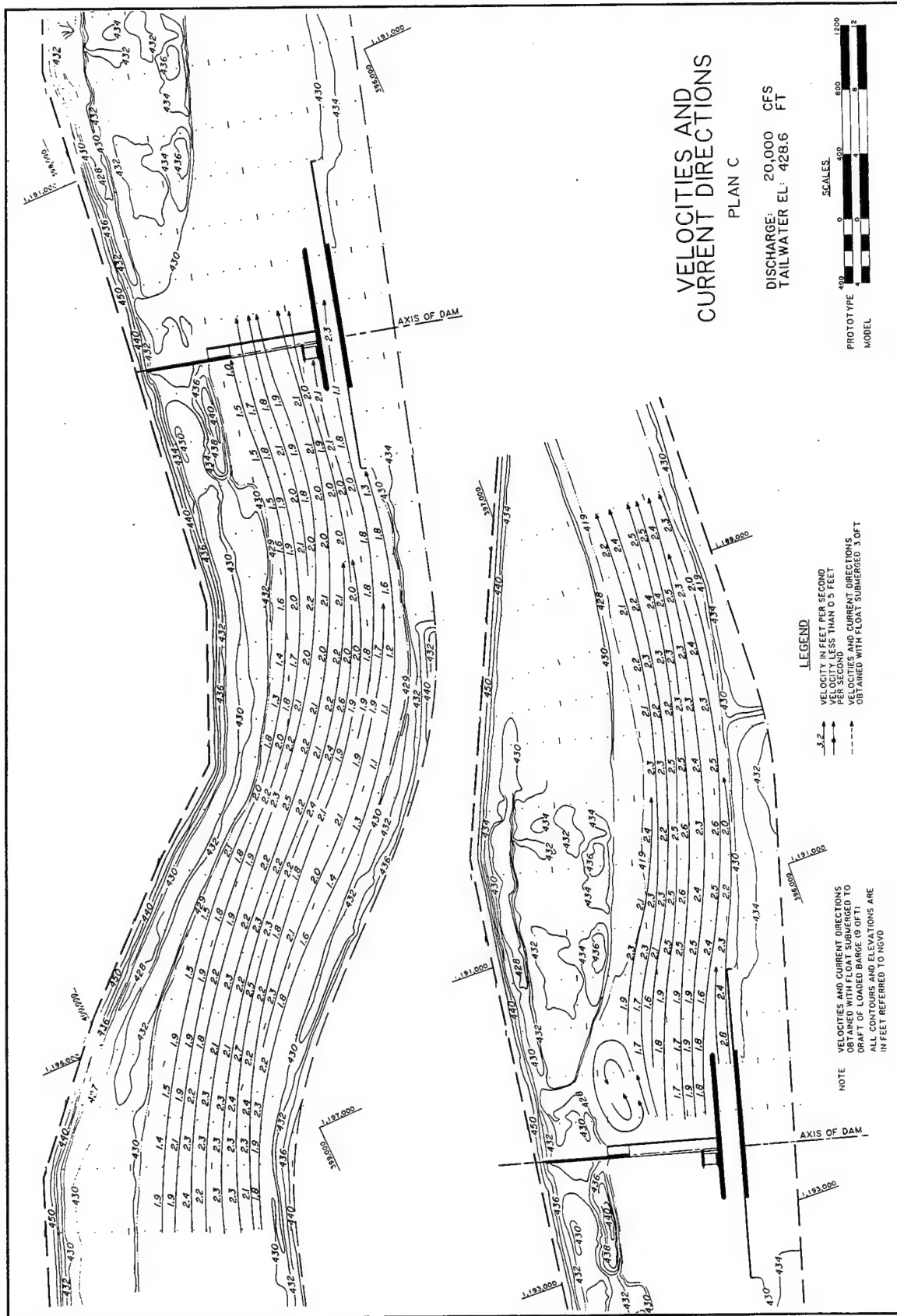
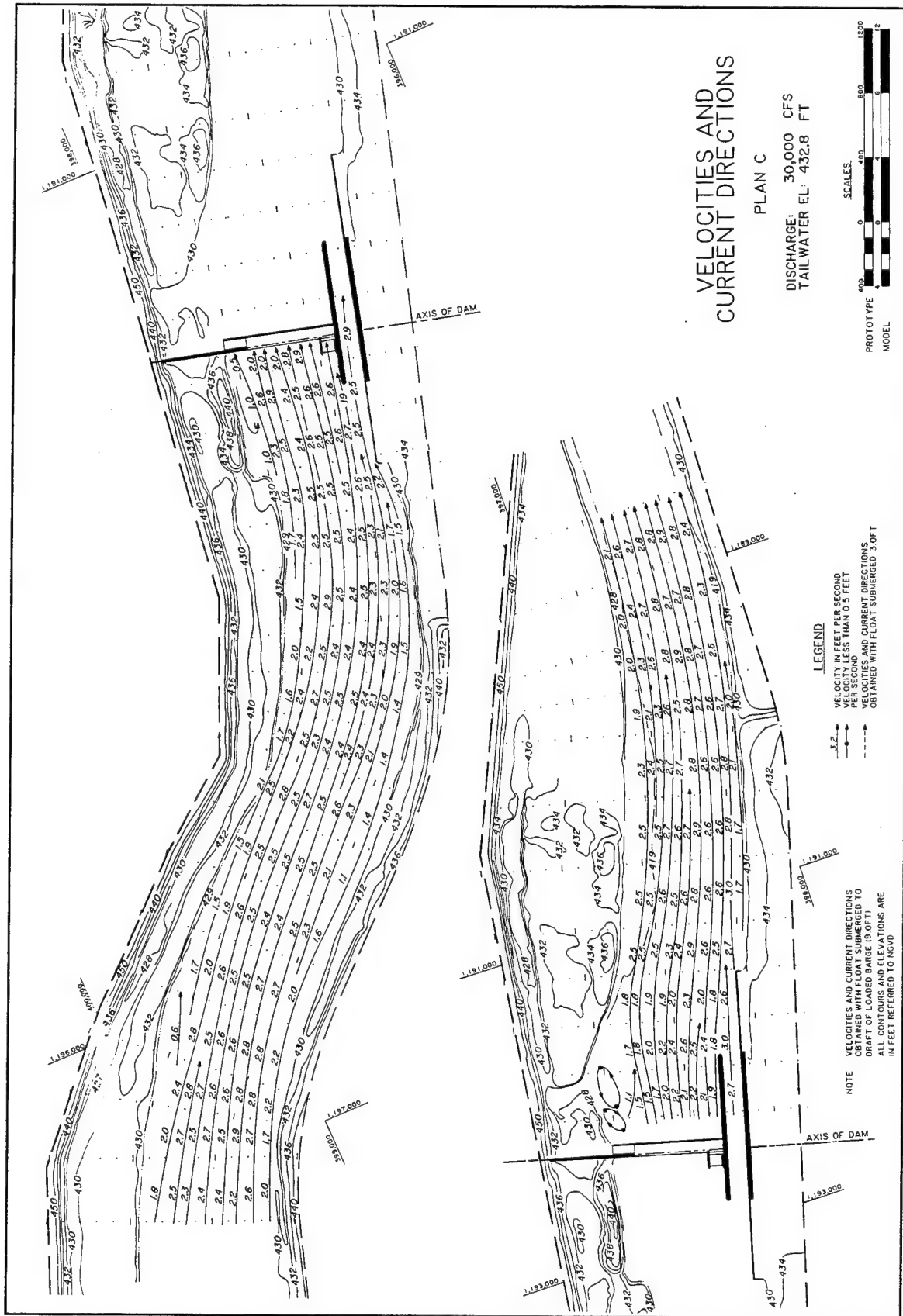
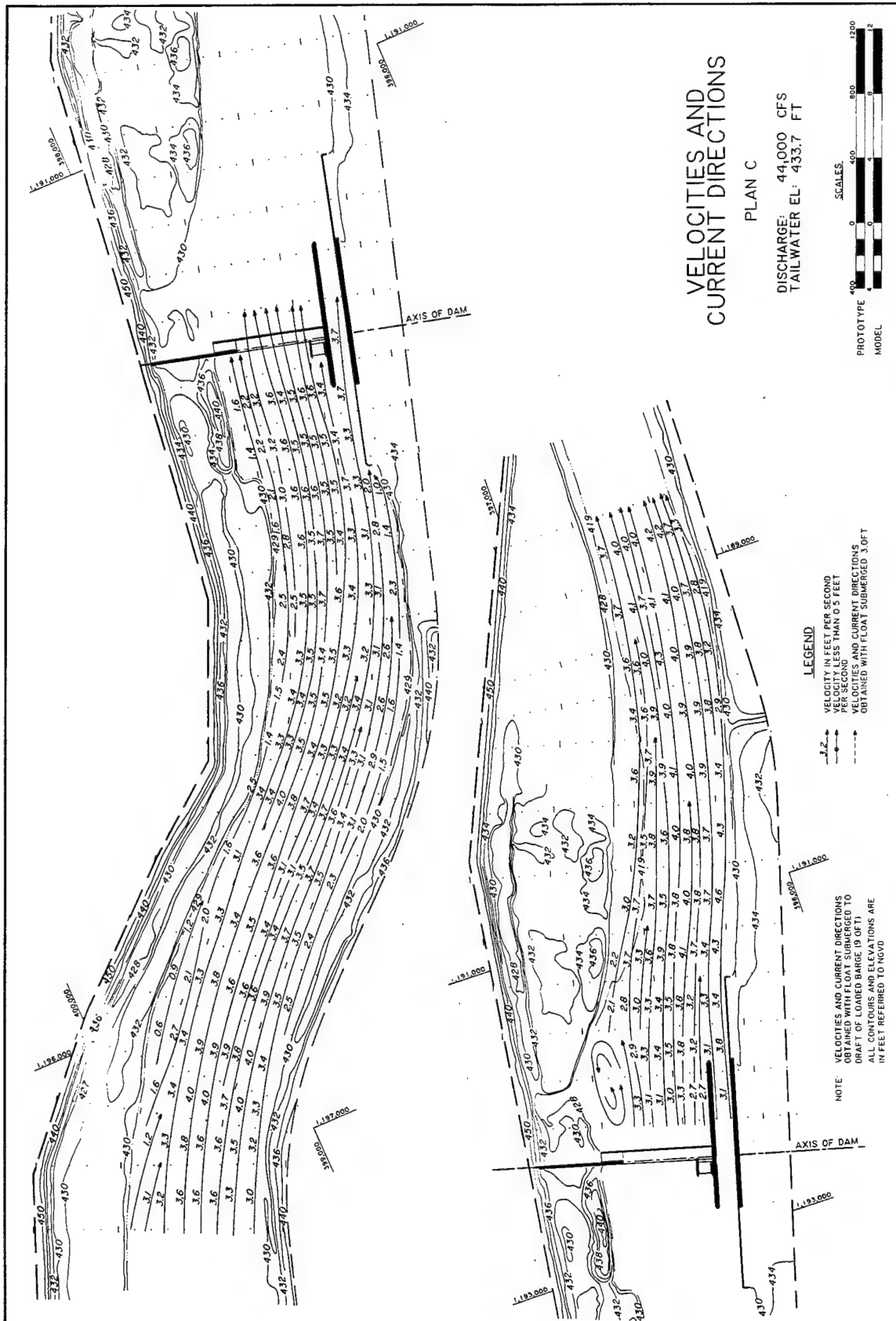


Plate 32













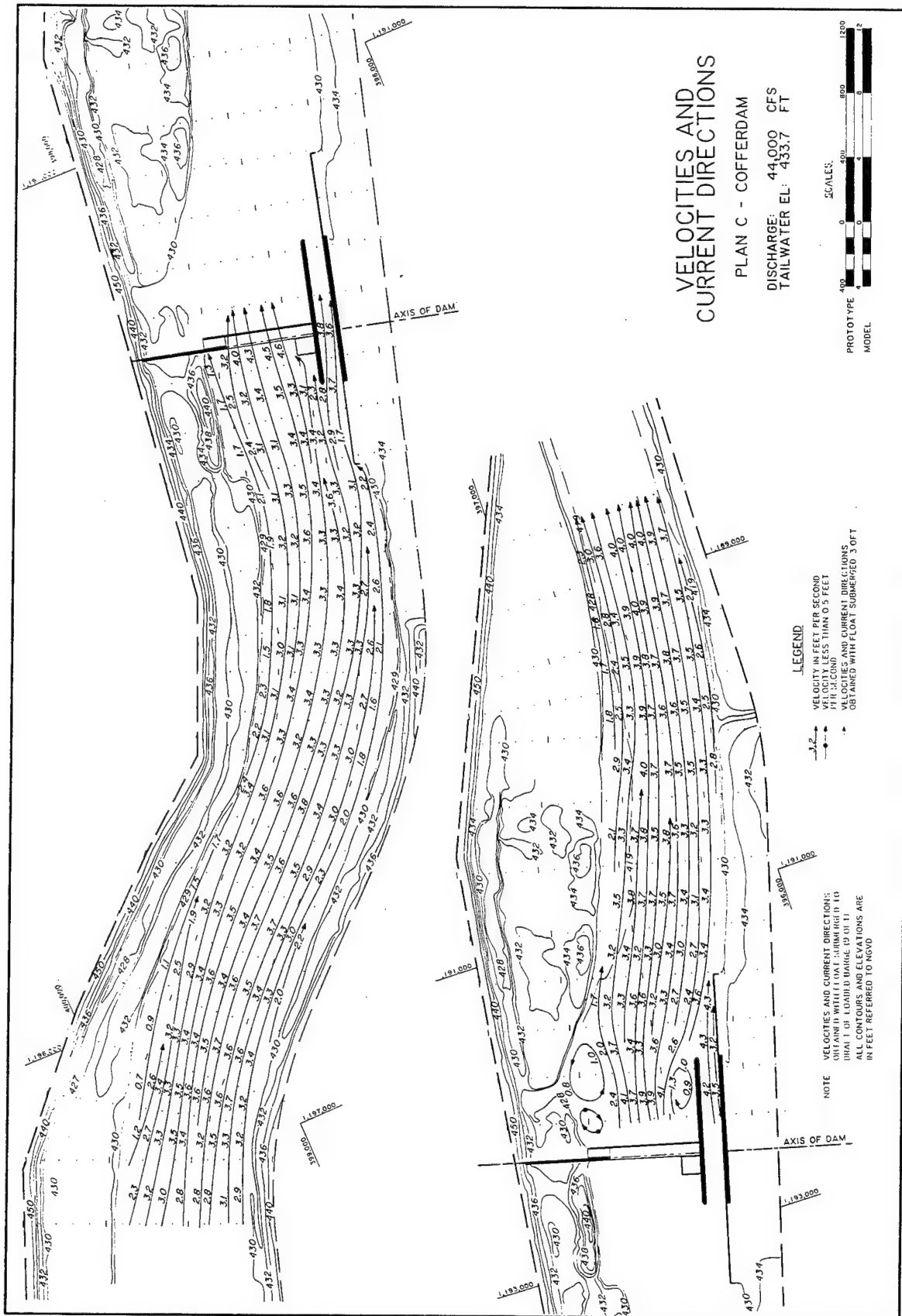
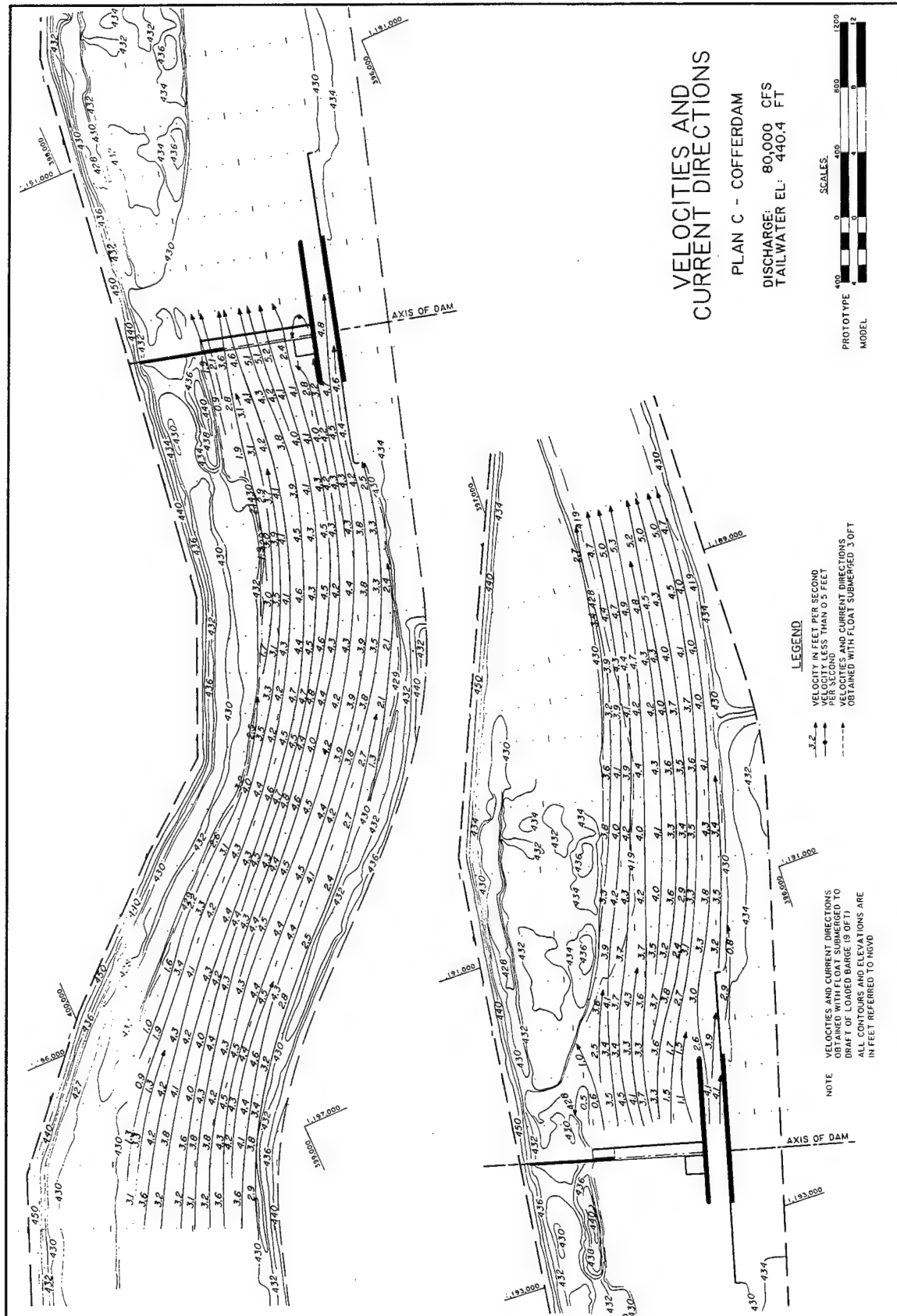


Plate 42





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13. ABSTRACT (Maximum 200 words) <p>LaGrange Lock and Dam are located on the Illinois River at river mile 80.2, 8 miles downstream from the city of Beardstown, IL. The structures include a 110-ft-wide by 600-ft-long navigation lock with a nominal lift (maximum) of 10 ft; a 540-ft-wide navigable pass with 135 wickets at 4.0 ft center to center; a 136-ft-wide regulating weir; and a 390-ft-long earth dam with top elevation of 430.0. (elevations (el) are in feet referred to the National Geodetic Vertical Datum). LaGrange Lock and Dam maintains a 78-mile-long navigation pool at el 429.0 that extends upstream to the Peoria Lock and Dam near Peoria, IL. A fixed-bed model reproduced about 2.1 miles of the Illinois Waterway and adjacent overbank to an undistorted scale of 1:100.</p> <p>The model investigation was concerned with alleviating some problems of the wicket dam by replacing some of the wickets adjacent to the lock with a submersible tainter gate. The tainter gate would regulate the navigation pool under normal conditions and could be submerged to pass heavy ice flows. The tainter gate eliminates the need for using the wickets for pool regulation, therefore greatly reducing the raising and lowering of the wickets. The model investigation was necessary for evaluation of the effects of the proposed tainter gate on navigation conditions, water-surface slopes through the reach, and the potential for scouring of the channel downstream of the proposed tainter gate. Results of the investigation</p> <p style="text-align: right;">(Continued)</p>			
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revealed reducing the width of the navigation pass from 540 ft to 396 ft by installation of a 244-ft-wide tainter gate structure could be hazardous for navigation, especially with riverflows of 20,000 cfs and greater. However, replacing part of the wicket dam with a 100-ft-wide tainter gate structure and leaving a 440-ft-wide navigation pass provided satisfactory clearance for tows to safely maneuver through the reach. Moving the proposed 100-ft-wide tainter gate structure upstream of the wicket dam did not adversely affect navigation conditions through the reach and provided a better design for construction of the structure. The proposed tainter gate would decrease the outdraft along the upper guide wall with controlled riverflows and slightly improve navigation conditions into the upper lock approach. With open riverflows, opening the lock as a floodway improved the current alignment in the vicinity of the structures, eliminated the eddy in the lower lock approach, reduced the velocities through the navigation pass slightly, and reduced the amount of maneuvering required for tows to navigate the reach.

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